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(71) Applicant *(for all designated States except US)*: **QUANTUMBEAM LIMITED** [GB/GB]; Abbey Barns, Duxford Road, Ickleton, Cambridgeshire CB10 1SX (GB).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **GREEN, Alan, Edward** [GB/GB]; Quantumbeam Limited, Abbey Barns, Duxford Road, Ickleton, Cambridgeshire CB10 1SX (GB). **MORRISON, Euan** [GB/GB]; Quantumbeam Limited, Abbey Barns, Duxford Road, Ickleton, Cambridgeshire CB10 1SX (GB). **REYNOLDS, Michael** [GB/GB]; Scientific Generics Limited, Harston Mill, Harston, Cambridgeshire CB2 5GG (GB).

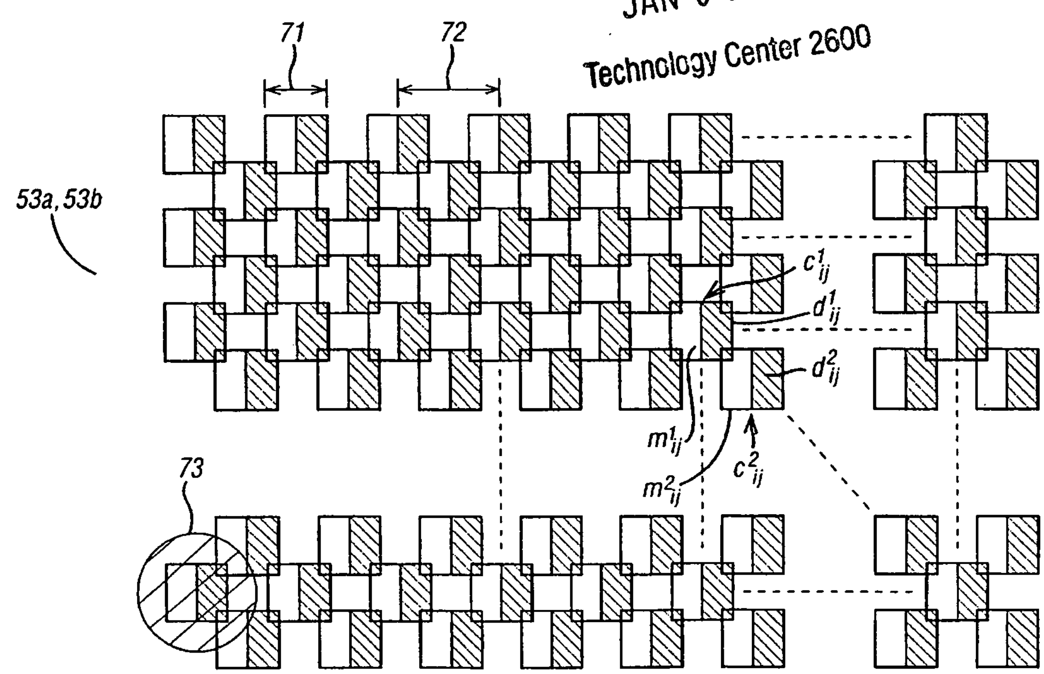
(74) Agents: **BERESFORD, Keith, Denis, Lewis** et al.; Beresford & Co., 2-5 Warwick Court, High Holborn, London WC1R 5DH (GB).

(81) **Designated States** *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: OPTICAL FREE SPACE SIGNALLING SYSTEM



(57) **Abstract:** A signalling system is provided which employs one or more arrays of communication elements together with an additional optical element for increasing the apparent packing density of the elements in the arrays. In one embodiment, this is achieved by using a microlens array matched with the array of communication elements. In another embodiment two arrays are provided which are optically combined with a beamsplitter. In a third embodiment, two optical systems are provided which are offset in angle from each other so that there is a different mapping between position in the array and position within the field of view.

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INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B10/207 H04B10/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 98 35328 A (GREEN ALAN EDWARD ;PETTIGREW ROBERT MARTIN (GB); SCIENT GENERICS L) 13 August 1998 (1998-08-13) cited in the application	31-36
A	abstract; claims 1,2; figures 1-4,9-11 page 2, line 25 -page 3, line 15	1-17, 21-30
Y	GB 2 186 457 A (GEC AVIONICS) 12 August 1987 (1987-08-12) abstract; figures 2,3	31-36

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 October 2000	12/10/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Goudelis, M

INTERNATIONAL SEARCH REPORT

International Application No
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9835328 A	13-08-1998	AU 6000898 A	26-08-1998
		EP 0960492 A	01-12-1999
GB 2186457 A	12-08-1987	NONE	

Form PCT/ISA/210 (patent family annex) (July 1992)

PA NT COOPERATION TREAT

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 03 April 2001 (03.04.01)	
International application No. PCT/GB00/02668	**Applicant's or agent's file reference** AM/1829899
International filing date (day/month/year) 10 July 2000 (10.07.00)	**Priority date** (day/month/year) 08 July 1999 (08.07.99)
Applicant GREEN, Alan, Edward et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

30 January 2001 (30.01.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Juan Cruz Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

BERESFORD, Keith, Denis, Lewis
Beresford & Co.
2-5 Warwick Court
High Holborn
London WC1R 5DH
ROYAUME-UNI

Date of mailing (day/month/year) 13 March 2001 (13.03.01)	
Applicant's or agent's file reference AM/1829899	**IMPORTANT NOTIFICATION**
International application No. PCT/GB00/02668	**International filing date** (day/month/year) 10 July 2000 (10.07.00)

1. The following indications appeared on record concerning:
[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address	State of Nationality	State of Residence
QUANTUMBEAM LIMITED GREEN Alan Edward MORRISON, Euan REYNOLDS, Michael	GB	GB
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:
[ ] the person [ ] the name [X] the address [ ] the nationality [ ] the residence

Name and Address	State of Nationality	State of Residence
QUANTUMBEAM LIMITED Harston Mill Harston Cambridgeshire CB2 5GG United Kingdom	GB	GB
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:
Please note the change of address of all applicant/inventors.

4. A copy of this notification has been sent to:
[X] the receiving Office
[X] the International Searching Authority
[ ] the International Preliminary Examining Authority
[X] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Lazar Joseph Panakal Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference AM/1829899	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/GB 00/02668	International filing date *(day/month/year)* 10/07/2000	(Earliest) Priority Date *(day/month/year)* 08/07/1999
Applicant SCIENTIFIC GENERICS LIMITED		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

      [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

      [ ] contained in the international application in written form.
      [ ] filed together with the international application in computer readable form.
      [ ] furnished subsequently to this Authority in written form.
      [ ] furnished subsequently to this Authority in computer readble form.
      [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
      [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [ ] the text is approved as submitted by the applicant.
   [X] the text has been established by this Authority to read as follows:

   OPTICAL FREE SPACE SIGNALLING SYSTEM

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 4

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/02668

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Date of the actual completion of the international search	Date of mailing of the international search report
5 October 2000	12/10/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Goudelis, M

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/02668

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9835328 A	13-08-1998	AU 6000898 A	26-08-1998
		EP 0960492 A	01-12-1999
GB 2186457 A	12-08-1987	NONE	

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9916422.0 13 July 1999 (13.07.1999) GB

(71) Applicant *(for all designated States except US)*: **SCIENTIFIC GENERICS LIMITED** [GB/GB]; Harston Mill, Harston, Cambridgeshire CB2 5NH (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **GREEN, Alan, Edward** [GB/GB]: Scientific Generics Limited, Harston Mill, Harston, Cambridgeshire CB2 5NH (GB). **MORRISON, Euan** [GB/GB]; Scientific Generics Limited, Harston Mill, Harston, Cambridgeshire CB2 5NH (GB). **REYNOLDS, Michael** [GB/GB]: Scientific Generics Limited, Harston Mill, Harston, Cambridgeshire CB2 5NH (GB).

(74) Agents: **BERESFORD, Keith, Denis, Lewis** et al.; Beresford & Co., 2-5 Warwick Court, High Holborn, London WC1R 5DH (GB).

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(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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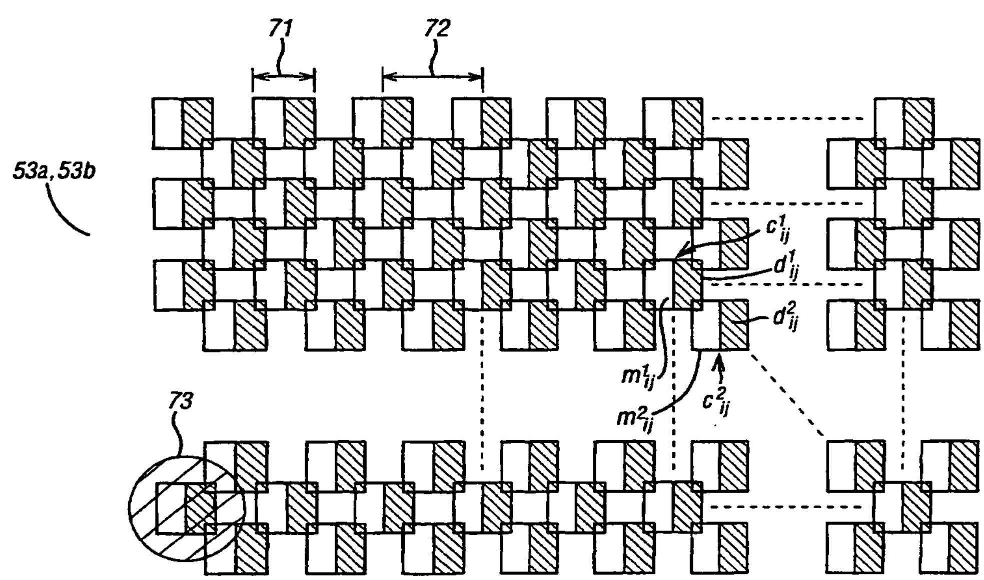
(54) Title: SIGNALLING SYSTEM



(57) **Abstract:** A signalling system is provided which employs one or more arrays of communication elements together with an additional optical element for increasing the apparent packing density of the elements in the arrays. In one embodiment, this is achieved by using a microlens array matched with the array of communication elements. In another embodiment two arrays are provided which are optically combined with a beamsplitter. In a third embodiment, two optical systems are provided which are offset in angle from each other so that there is a different mapping between position in the array and position within the field of view.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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JC13 Rec'd PCT/PTO 08 JAN 2002

16/pxts

SIGNALLING SYSTEM

The present invention relates to a signalling system. One aspect of the invention relates to an optical free space signalling method and apparatus.

The applicant has proposed in their earlier International application WO98/35328 a point to multipoint data transmission system which uses a retroreflector to receive collimated laser beams from a plurality of user terminals, to modulate the received laser beams and to reflect them back to the respective user terminals. This point to multipoint data transmission system employs pixelated reflector/modulator arrays and a telecentric optical lens systems. The system operates by assigning each user of the system a unique pixel in the array. Each pixel in the array is matched to a unique angular position in the field of view of the telecentric optical lens system.

The inventors have found, however, that the system described in this International application suffers from the problem that there are locations within the field of view of the optical lens system where communication between the transmitter and receiver cannot occur reliably. The inventors have identified that this is because of the pixelated nature of the reflector/modulator array used in the system. In particular, since there are gaps between the pixels in the array, there are areas in the field of view of the

optical lens system which do not correspond to the pixels of the reflector/modulator array. This problem can be minimised by minimising the gaps between the pixels. However, in practice this is difficult to achieve since the pixels must be electrically isolated from each other and space must be provided to allow connections to be made to the individual pixels.

The present invention aims to alleviate the problems described above by providing at least one additional optical element to increase the apparent packing density of the communication pixels.

According to one aspect, the present invention provides a communication system which employs a plurality of arrays of communication elements which are optically combined to increase their effective packing density (i.e. to increase the effective area covered by the communication elements compared to the gaps between the elements). Preferably the plurality of arrays are arranged so that the packing density is increased to 100% to provide maximum coverage.

According to another aspect, the present invention provides an optical communication system having an array of optical communication elements and a micro lens array positioned in front of the array of elements to increase the apparent packing density of the elements.

According to another aspect, the present invention

provides an optical communication system having two or more telecentric optical systems which are offset in angle from each other and which include a respective array of communication elements.

Exemplary embodiments of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a video broadcast system for supplying video signals for a plurality of television channels, to a plurality of remote users;

Figure 2 is a schematic block diagram of a local distribution node and a user terminal which forms part of the video broadcast system shown in Figure 1;

Figure 3 is a schematic diagram of a retroreflector array and lens system employed in the local distribution node shown in Figure 2;

Figure 4 is a schematic diagram of an optically combined pixelated retroreflector array which forms part of the system shown in Figure 3;

Figure 5 is a schematic diagram of a data distribution system;

Figure 6 is a schematic diagram of a local distribution node and a user terminal which forms part of the data

distribution system shown in Figure 5;

Figure 7 is a schematic diagram of an emitter and detector array and lens system employed in the local distribution node shown in Figure 6;

Figure 8 is a schematic diagram of a data distribution system for supplying data to a plurality of users;

Figure 9 is a schematic diagram of an array of emitters and detectors which forms part of one of the user terminals in the system shown in Figure 8;

Figure 10 is a schematic diagram of an alternative form of local distribution node and user terminal which can be used in the data distribution system shown in Figure 1;

Figure 11 is a schematic diagram of an alternative form of local distribution node and user terminal which can be employed in the data distribution system shown in Figure 1;

Figure 12 is schematic diagram of an alternative form of local distribution node and user terminal which can be employed in the data distribution system shown in Figure 1;

Figure 13 is a schematic diagram of an alternative form of local distribution node and user terminal which can be employed in the data distribution system shown in Figure

1;

Figure 14 is a schematic diagram of an alternative form of an optically combined pixelated communications cell array which may be used in any of the above embodiments;

Figure 15 is a schematic diagram of an alternative form of an optically combined pixelated communication cell array which may be used in any of the embodiments described above;

Figure 16 is a schematic block diagram of a retroflector array and lens system which may be employed in the local distribution node shown in Figure 2 and which includes a micro lens array for increasing the apparent packing density of the communication cells; and

Figure 17 is a schematic block diagram of two telecentric optical systems and modulator arrays which are offset at an angle from each other.

Figure 1 schematically illustrates a video broadcast system for supplying video signals, for a plurality of television channels, to a plurality of remote users. As shown in Figure 1, the system comprises a central distribution system 1 which transmits optical video signals to a plurality of local distribution nodes 3 via a bundle of optical fibres 5. The local distribution nodes 3 are arranged to receive the optical video signals transmitted from the central distribution system 1 and to

transmit relevant parts of the video signals to respective user terminals 7 (which are spatially fixed relative to the local distribution node 3) as optical signals through free space, i.e. not as optical signals along an optical fibre path.

In this embodiment, the video data for all the available television channels is transmitted from the central distribution system 1 to each of the local distribution nodes 3, each user terminal 7 informs the appropriate local distribution node 3 which channel or channels it wishes to receive (by transmitting an appropriate request) and, in response, the local distribution node 3 transmits the appropriate video data, to the respective user terminals 7. Each local distribution node 3 does not, however, broadcast the video data to the respective user terminals 7. Instead, each local distribution node 3 is arranged (i) to receive an optical beam transmitted from each of the user terminals 7 which are in its locality, (ii) to modulate the received beams with the appropriate video data for the desired channel or channels, and (iii) to reflect the modulated beams back to the respective user terminals 7. In addition to being able to receive optical signals from the central distribution system 1 and from the user terminal 7, each of the local distribution nodes 3 can also transmit optical data, such as status reports, back to the central distribution system 1 via the respective optical fibre bundle 5, so that the central distribution system 1 can monitor the status of the distribution network.

Figure 2 schematically illustrates in more detail the main components of one of the local distribution nodes 3 and one of the user terminals 7 of the system shown in Figure 1. As shown in Figure 2, the local distribution node 3 comprises a communications control unit 11 which (i) receives the optical signals transmitted along the optical fibre bundle 5 from the central distribution system 1; (ii) regenerates the video data from the received optical signals; (iii) receives messages 12 transmitted from the user terminals 7 and takes appropriate action in response thereto; and (iv) converts the appropriate video data into data 14 for modulating the respective light beams 15 received from the user terminals 7. In converting the video data into modulation data 14, the communications control unit 11 will encode the video data with error correction coding and coding to reduce the effects of inter-symbol-interference and other kinds of well known sources of interference such as from the sun and other light sources.

The local distribution node 3 also comprises a retro-reflector and modem unit 13, which is arranged to receive the optical beams 15 from the user terminals 7 which are within its field of view, to modulate the respective light beams with the appropriate modulation data 14 and to reflect the modulated beams back to the respective user terminals 7. In the event that an optical beam 15 received from one of the user terminals 7 carries a message 12, then the retro-reflector and modem unit 13

retrieves the message 12 and sends it to the communications control unit 11 where it is processed and the appropriate action is taken. In this embodiment, the retro-reflector and modem unit 13 has a horizontal field of view which is greater than +/- 50° and a vertical field of view of approximately +/- 5°.

Figure 2 also shows the main components of one of the user terminals 7. As shown, the user terminal 7 comprises a laser diode 17 for outputting a laser beam 19 of coherent light. In this embodiment, the user terminals 7 are designed so that they can communicate with the local distribution node 3 within a range of 150 metres with a link availability of 99.9 per cent. To achieve this, the laser diode 17 is a 50 mW laser diode which outputs a laser beam having a wavelength of 850 nm. This output laser beam 19 is passed through a collimator 21 which reduces the angle of divergence of the laser beam 19. The resulting laser beam 23 is passed through a beam splitter 25 to an optical beam expander 27, which increases the diameter of the laser beam for transmittal to the retro-reflector and modem unit 13 located in the local distribution node 3. The optical beam expander 27 is used because a large diameter laser beam has a smaller divergence than a small diameter laser beam. Additionally, increasing the diameter of the laser beam also has the advantage of spreading the power of the laser beam over a larger area. Therefore, it is possible to use a higher powered laser diode 17 whilst still meeting eye-safety requirements.

Using the optical beam expander 27 has the further advantage that it provides a fairly large collecting aperture for the reflected laser beam and it concentrates the reflected laser beam into a smaller diameter beam. The smaller diameter reflected beam is then split from the path of the originally transmitted laser beam by the beam splitter 25 and focused onto a photo-diode 29 by a lens 31. Since the operating wavelength of the laser diode 17 is 850nm, a silicon avalanche photo-diode (APD) can be used, which is generally more sensitive than other commercially available photo detectors, because of the low noise multiplication which can be achieved with these devices. The electrical signals output by the photo-diode 29, which will vary in dependence upon the modulation data 14, are then amplified by the amplifier 33 and filtered by the filter 35. The filtered signals are then supplied to a clock recovery and data retrieval unit 37 which regenerates the clock and the video data using standard data processing techniques. The retrieved video data 38 is then passed to the user unit 39, which, in this embodiment, comprises a television receiver in which the video data is displayed to the user on a CRT (not shown).

In this embodiment, the user unit 39 can receive an input from the user, for example indicating the selection of a desired television channel, via a remote control unit (not shown). In response, the user unit 39 generates an appropriate message 12 for transmittal to the local distribution node 3. This message 12 is output to a

laser control unit 41 which controls the laser diode 17 so as to cause the laser beam 19 output from the laser diode 17 to be modulated with the message 12. As those skilled in art will appreciate, in order that the data being transmitted in opposite directions do not interfere with each other, different modulation techniques should be employed. For example, if the amplitude of the laser beam 15 is modulated by the local distribution node 3, then the laser control unit 41 should modulate, for example, the phase of the transmitted laser beam. Alternatively, the laser control unit 41 could apply a small signal modulation to the laser beam 19 to create a low-bandwidth control channel between the user terminal 7 and the local distribution node 3. This is possible provided the detector in the local distribution node 3 can detect the small variation in the amplitude of the received laser beam. Furthermore, such a small signal amplitude modulation of the laser beam would not affect a binary "on" and "off" type modulation which could be employed by the retro-reflector and modem unit 13.

The structure and function of the components in the user terminal 7 are well known to those skilled in the art and a more detailed description of them shall, therefore, be omitted.

Figure 3 schematically illustrates the retro-reflector and modem unit 13 which forms part of the local distribution node 3 shown in Figure 2. As shown, in this embodiment, the retro-reflector and modem unit 13

comprises a wide angle telecentric lens system 51, two arrays of modulators and detectors 53a and 53b and a beamsplitter 54 for dividing beams from the telecentric lens system 51 between the modulator/detector arrays 53a and 53b. In this embodiment, the telecentric lens system 51 comprises lens elements 61 and 55 and a stop member 57, having a central aperture 59. The size of the aperture 59 is a design choice and depends upon the particular requirements of the installation. The structure and function of a telecentric lens system is described in the applicants earlier International application WO 98/35328, the content of which is incorporated herein by reference.

As is illustrated in Figure 3 by the two sets of rays 67 and 69, laser beams from different sources are focused onto different parts of the arrays of modulators/detectors 53a, 53b. Therefore, by using an array of separate modulators and detectors, the laser beams 15 from all the user terminals 7 can be separately detected and modulated by a respective modulator and detector pair.

In this embodiment, each of the modulator/detector arrays 53a and 53b comprises 100 columns and 10 rows of modulator/detector cells. As shown in Figure 3, these arrays are located at the back focal plane 62a and 62b of the lens system 51. The cells of these arrays are spatially staggered from each other so that the cells in array 53b are optically located in the spaces between the

cells of array 53a. This is schematically illustrated in Figure 4, which shows the optically combined modulator/detector arrays 53a and 53b. As shown, the cells c^2_{ij} of the array 53b are positioned so that the are optically located between the cells c^1_{ij} of the array 53a. As a result, the packing density of the cells is significantly increased compared to the packing density of the individual arrays 53a and 53b. As shown, each modulator/detector cell c_{ij} comprises a modulator m_{ij} and a detector d_{ij} located adjacent the corresponding modulator. In this embodiment, the size 71 of the cells c_{ij} is between 50 and 200 μm, with the spacing (centre to centre) 72 between the cells being slightly smaller than the cell size 71.

As shown in Figure 4, the telecentric lens 51 is designed so that the spot size of a focused laser beam from one of the user terminals 7 corresponds with the size 71 of one of the modulator/detector cells c_{ij}, as illustrated by the shaded circle 73 shown in Figure 4, which covers the modulator/detector cell $c^1_{10\,1}$. The way in which the laser beams from the user terminals 7 are aligned with the retro-reflector and the way in which the system initially assigns the modulator/detector cells to the respective user terminals is described in WO 98/35328 and will not be described again here.

In this embodiment, Quantum Confined Stark Effect (QCSE, sometimes also referred to as Self Electro-optic Effect Devices or SEEDs) modulators, developed by the American

Telephone and Telegraph Company (AT&T), are used for the modulators m_{ij}. The structure and function of these QCSE modulators is described in WO 98/35328 and will not be given here. In this embodiment, each of the detectors d_{ij} comprises a photo-diode which is connected to an associated amplifier, filter and clock recovery and data retrieval unit similar to those employed in the user terminal 7 shown in Figure 2, which operate to detect any modulation of the corresponding laser beam and to regenerate any messages 12 which are transmitted from the corresponding user terminal 7. All the recovered messages 12 are then transmitted back to the communications control unit 11 where they are processed and appropriate actions are taken.

Figure 5 schematically shows a data distribution system which employs a point to multipoint signalling system. The data distribution system is similar to the video data distribution system shown in Figure 1, except that data is passed in only one direction, from the central distribution system 1 to the user terminals 7. Such a data distribution system can be employed to distribute information relating to, for example, the prices of shares which are bought and sold on a stock market. In such an application, the individual user terminals 7 would comprise a display unit for displaying the new prices of the stocks to the traders so that they can be kept up-to-date with changes in the share prices. Alternatively, such a one-way data distribution system could be used in railway stations, airports and the like

for informing passengers of arrivals and departures etc.

The local distribution node 3 used in this embodiment is similar to the local distribution node of the system shown in Figure 1. The only difference is that the cells in the arrays do not include detectors d_{ij}, for receiving communications transmitted from the user terminals 7. Similarly, the user terminals 7 are similar to those of the first embodiment except that there is no need for the optical beam expander in front of the beam splitter nor a laser control circuit for modulating the laser diode for transmitting messages to the local distribution nodes. The remaining components of this embodiment are the same and will not, therefore, be described again.

In the above embodiments, a retro-reflecting communication system was described. As those skilled in the art will appreciate, the above technique for increasing the packing density is also applicable to systems which use an array of light emitters rather than an array of retro-reflectors. Figure 6 schematically illustrates in more detail the main components of one of the local distribution nodes 3 and one of the user terminals 7 of such an embodiment. As shown in Figure 6, the local distribution node 3 comprises a communications control unit 11 which (i) receives the optical signals transmitted along the optical fibre 5 from the central distribution system 1; (ii) regenerates the video data from the received optical signals; (iii) receives messages 12 transmitted from the user terminals 7 and

takes appropriate action in response thereto; and (iv) converts the appropriate video data into data 14 for transmission from the emitter elements of the emitter/detector array and lens system 80. The emitter/detector array and lens system 80, which is arranged (i) to receive the optical beams 15 from the user terminals 7 which are within its field of view and to transmit the received messages 12 to the communications control unit 11 where they are processed and the appropriate action taken; and (ii) to transmit the respective video data 14, via optical beams 15, to the respective user terminals 7.

As shown in Figure 6, the user terminal 7 is identical to that of Figure 2.

Figure 7 schematically illustrates the emitter and the detector array and lens system 80 which forms part of the local distribution node 3 shown in Figure 6. As shown, in this embodiment, the emitter and detector array and lens system 80 comprises a lens system 89, two arrays of emitters/detectors 90a, 90b and a beam splitter 54 located between the arrays 90 and the lens system 89. As shown, the lens system 89 comprises a wide angled lens 55 and a convex lens 87 which operate to provide a wide field of view for the emitter and detector array and lens system 80. In this embodiment, the lens system 89 is not telecentric. Each of the emitter/detector arrays 90a and 90b comprise a regular array of communication cells similar to the cells formed in the modulator/detector

arrays of the first embodiment, except with the modulators replaced by light emitters. In this embodiment, the emitters are formed from vertical cavity surface emitting lasers (hereinafter referred to as VCSELs). The VCSEL array is preferred because the array can be manufactured from a single semiconductor wafer, without having to cut the wafer. This allows a higher number of the emitter elements per unit area than would be the case with an array made from traditional laser diodes.

These VCSEL arrays, manufactured and sold by CSEM SA (Badenerstrasse 569, 8048 Zurich, Switzerland), operate in a power range of between 1 and 30 mW and output a laser beam having a wavelength the same as conventional laser diodes. Again, the cells of the arrays 90a and 90b are spatially arranged so that, through the operation of the beam splitter 54, the cells of the arrays are interleaved with each other like the cells shown in Figure 4.

In this embodiment, the VCSEL emitters e_{ij} in the emitter arrays 90a, 90b are selectively addressable and the data 14 from the communications control unit includes respective data for each VCSEL emitter e_{ij}. The data for each VCSEL emitter may be the same or it may be different, depending on the application. As shown in Figure 7, the light output by each emitter e_{ij} in the arrays 90a, 90b is a diverging beam, the divergence being primarily caused by diffraction at the emitting aperture

of the laser. The lens system 89 collects the diverging beam from each emitter and forms it into a collected beam. As those skilled in the art will appreciate, and as illustrated by the light rays 95 and 97, the angle at which the collected beam leaves the exit pupil of the lens depends on the spatial position of the emitter in the arrays 90a or 90b. Therefore, each emitter in each array maps to a particular angle in space and can therefore communicate with a respective user terminal 7.

In the above embodiments, simplex and duplex data distribution systems have been described in which a number of fixed user terminals can communicate with a local distribution node. An embodiment will now be described with reference to Figures 8 and 9 which describe a data distribution system similar to the system described with reference to Figures 5 to 7 except that some of the user terminals 7 (such as user terminal u^1_m) can receive data from more than one local distribution node 3. In this way, some of the user terminals can receive twice the amount of data from the local distribution nodes or, if the local distribution nodes transmit the same data, then some of the user terminals 7 will have an uninterrupted communication link even if the line of sight linked with one of the local distribution nodes become blocked.

In this embodiment, the local distribution nodes 3 are substantially the same as the local distribution node shown in Figure 7, except that the lens system is

telecentric, like the lens system shown in Figure 3, and the arrays are just emitter rays. In this embodiment, telecentric lenses are used since this allows the collection efficiency (of light from the emitter arrays 90) of the lens to be constant across the emitter arrays. Therefore, provided that all the emitter elements are the same, the intensity of the light output from the local distribution node will be the same for each emitter. In contrast, with a non-telecentric lens, the intensity of the light output from the local distribution node will be greater for light emitted by emitters in the centre of the array than for those at the edge. The use of a telecentric lens also avoids the various cosine fall-off factors which are well known in conventional lenses.

In order to allow the user terminals to be able to simultaneously receive different communications from the different local distribution nodes 3, the user terminals include arrays of detector cells similar to the arrays of emitter cells located in the local distribution nodes 3. Figure 9 schematically illustrates the lens system and detector array 100 which forms part of a user terminal 7 and which replaces the lens 31 and photo diode 29 of Figure 6. As shown, the lens system 101 comprises a wide angle lens 103 and a convex lens 105, and operates to focus light received from different local distribution nodes 3 (represented by light rays 106 and 107) onto a beamsplitter 109 which divides the beams between the two detector arrays 108a and 108b. In this embodiment, the detector cells in the two detector arrays 108a and 108b

are spatially arranged so that they are interleaved with each other, like the cells shown in Figure 4. As those skilled in the art will appreciate, by providing two of these detector arrays optically combined by the beam splitter 109, the packing density of the detector arrays can be increased over the packing density obtainable through a single array.

As those skilled in the art will appreciate and as mentioned above, one of the advantages of this embodiment is that if one of the laser beams (106 or 107) from one of the local distribution nodes 3 is blocked, then the user terminal 7 will still receive the data from the other beam. Another advantage of this embodiment is that since both sides of the free space communications link use wide angled lenses, their fields of view are relatively large. Therefore, successful communications can still be carried out even if the user terminal 7 moves relative to the local distribution node 3, provided both remain within the other's field of view.

Another advantage of this embodiment is that if the user terminals 7 do move relative to the local distribution nodes 3, then they can determine either when they are about to move out of the field of view of one of the local distribution nodes 3 or when one of the local distribution nodes 3 is about to move out of their field of view. This is possible because as the user terminals 7 move, the laser beams from the local distribution nodes 3 move over the respective detector array 108a, 108b and

the user terminals 7 can detect this by sampling the signals from the detector cells in their arrays. In such an embodiment, if the user terminal 7 determines that the laser beam from one of the local distribution nodes 3 is about to move off the side of the detector array 108a, 108b and if the user terminal 7 is not receiving data from another local distribution node 3, then the user terminal 7 may be configured so as to warn the user that connection to the central distribution system 1 is about to be lost. As those skilled in the art will appreciate, in such an embodiment where the user terminals 7 move relative to the local distribution nodes 3 (or vice versa), either side of the communication link can track the movement of the other side within its field of view by tracking the focussed laser beam from the other side as it moves over its emitter/detector arrays. This information can then be used to control the emitter and detector cell which is used in the communications link.

A simplex communications system was described above in which emitter arrays were provided in each of the local distribution nodes and detector arrays were provided in each of the user terminals. As those skilled in the art will appreciate, and as shown in Figure 10, the communication system shown in Figure 8 can be made into a duplex communication system by providing emitter and detector arrays in both the local distribution nodes 3 and the user terminals 7. Preferably, in such an embodiment, each side of the communications link would use a wide angled telecentric lens such as the one shown

in Figure 3, for the reasons mentioned above. Alternatively, as illustrated in Figure 11, emitter and detector arrays may be provided in the local distribution nodes 3 and retroreflector and modulator arrays may be provided in each of the user terminals 7. Alternatively still, as illustrated in Figure 12, a retroreflector and modem unit may be provided in each of the local distribution nodes 3 and emitter and detector arrays may be provided in each of the user terminals 7.

Alternatively still, retroreflector and modem units may be provided in both the local distribution nodes 3 and the user terminal 7. Such an embodiment is illustrated in Figure 13. As those skilled in the art will appreciate, in such an embodiment, either the local distribution node or the user terminal must also include a laser diode for illuminating the light reflectors of one of the retroreflectors. In the embodiment shown in Figure 13, this laser diode is provided in the local distribution node 3. As shown, light from the laser diode 111 is expanded and collimated by the lens 112 and used to illuminate the modulator array 113 via a polarising beamsplitter 114. Each element of the modulator array reflects or absorbs a part of the incident light in accordance with the electric bias applied to that element (which depends on the input modulation data 14). The reflected light then passes through the beamsplitter and a $\lambda/4$ wave plate 119 (for changing the polarisation of the reflected light from linear to circular) and lens 115 towards the user

terminal 7. The beam received at the user terminal is focussed by a lens 116 onto a retro-reflector array (including both modulators and detectors) 117 where the received light is both detected (to recover the modulation data 14) and modulated with data 12 and reflected back towards the local distribution node 3. As a result of this reflection, the "handedness" of the polarised light is inverted and therefore, when the reflected light passes again through the $\lambda/4$ wave plate 119, the linear polarisation of the received light is rotated by 90° relative to the transmitted light. Therefore, the reflected light is reflected by the polarising beamsplitter 114 towards the photodiode array 118, where the modulation data 12 is recovered. As those skilled in the art will appreciate, the techniques described above which are used to increase the effective packing density of the retro-reflectors may also be employed in this embodiment at one or at both ends of the communications link.

In the above embodiment, two arrays of modulators were combined using a beam splitter 54. As a result, the apparent packing density of the arrays of modulator/detector cells is increased. However, with 2D arrays, a packing density of 100% cannot be achieved with only two arrays of such modulator/detector cells. However, if four arrays of modulator/detector cells are used, each having a packing density of at least 25% (i.e. in which the gap between the pixels is equal to or greater than the pixel size), then by employing three

beamsplitters, these four arrays may be optically combined to achieve a 100% packing density. This is schematically illustrated in Figure 14.

Further, in some applications, users of the communication system will be distributed in a substantially horizontal plane. Therefore, in this case, a linear array of modulators/detectors is sufficient and a 100% packing density can be achieved through just two linear arrays, as illustrated in Figure 15.

In the above embodiments, two arrays of optical communication elements (such a light emitters, light reflectors and light detectors) were optically combined using beamsplitters in order to increase the packing density of the optical elements. The packing density of the optical elements can be effectively increased using other techniques. For example, an array of microlenses may be placed in front of the array of optical elements. In this case the microlens array would be arranged so that the centres of the microlens have the same grid spacing as that of the elements in the optical element array, so that each microlens acts as an optical system for an individual optical element. This is illustrated in Figure 16 which shows the way in which such an array of microlenses 135 may be placed in front of an array of optical communication elements (in this case an array of QCSE modulators 53). As illustrated in Figure 16, each of the microlenses 137 is located adjacent a modulator pixel 53-1, which, in this embodiment, are spaced apart along

the array 53 by regular intervals 53-2. As shown, each of the microlenses 137 acts to form a magnified image of the associated modulator pixel, so that, when viewed from the exit pupil of the telecentric optical system 51, the array appears to have a 100% packing density.

As those skilled in the art will appreciate, by using such a microlens array, the numerical aperture of the beam at the modulator pixel will be larger than without the lens by a factor equal to the linear magnification afforded by the microlens. With 30μm modulator elements and with a spacing between the elements of 5μm, the linear magnification required to achieve a 100% packing density is 1.167, and hence the numerical aperture at the pixel is increased by this factor. However, this is a relatively small increase in numerical aperture and in most cases is well within acceptable limits for the modulator pixel.

Another way of increasing the packing density of a single array of optical communication elements is to use two or more separate optical systems and arrays of communication elements. Such a system is schematically illustrated in Figure 17. As shown, the system includes two telecentric optical systems 120a and 120b and two arrays 125a and 125b of optical communication elements. This embodiment makes use of the fact that a beam 127 incident upon the transmitter or receiver is typically significantly larger than the telecentric stop of the telecentric lens. Therefore, the beam can be received by more than one

telecentric system. Therefore, by pointing the two telecentric lens systems in slightly different directions, as shown in Figure 17, the mapping between direction within the field of view and position on the arrays 125a and 125b, for the two arrays will be different. Therefore, by setting the appropriate offset angle between the two telecentric lens systems, the communications elements in the two arrays 125a and 125b can be arranged to intermesh in a similar manner to the embodiments which employ beamsplitters. As those skilled in the art will appreciate, this technique can achieve a 100% packing density without the additional optical loss associated with beamsplitters, but at the cost of additional telecentric optical systems.

In the retro-reflecting embodiments described above, an array of QCSE modulators were used in the retro-reflecting end of the communication link. These QCSE modulators either absorb or reflect incident light. As those skilled in the art will appreciate, other types of reflectors and modulators can be used. For example, a plane mirror may be used as the reflector and a transmissive modulator (such as a liquid crystal) may be provided between the lens and the mirror. Alternatively still, beamsplitters may be used to temporarily separate the path of the incoming beam from the path of the reflected beam and, in this case, the modulator may be provided in the path of the reflected beam so that only the reflected light is modulated. However, such an embodiment is not preferred since it requires additional

optical components to split the forward and return paths and then to re-combine the paths after modulation has been effected.

In the embodiments which employ a telecentric lens, the array of emitters or detectors or modulators are located substantially at the back focal plane of the telecentric lens. As those skilled in the art will appreciate, the telecentric lens can be adapted to have a back focal plane which is curved or partially curved. In this case, the array of emitters or detectors or modulators should also be curved or partially curved to match the back focal plane of the telecentric lens.

In the above embodiments, a point to multipoint signalling system has been described. As those skilled in the art will appreciate, many of the communications techniques described above will apply to point to point signalling systems, to multipoint to point signalling systems and multipoint to multipoint signalling systems.

In the embodiments described above which employ arrays of VCSEL emitters, the light generated by each of the emitters is modulated with the data to be transmitted to the other end of the communication link. The easiest way to modulate the light from the VCSEL emitters is to switch the emitters on and off to thereby amplitude modulate the light emitted from them. However, as those skilled in the art will appreciate, other modulation techniques, such as frequency or phase modulation may be

used. Further, as those skilled in the art will appreciate, other types of light emitters such as laser diodes and light emitting diodes may be used. An array of emitters could also be formed by a bundle of optical fibres, closely packed into a regular array with a laser diode coupled to the other end of each fibre. However, the use of such a bundle of optical fibres or the use of 2D arrays of laser diodes results in a greater beam divergence caused by diffraction at the emitting aperture which is of the order of ±20°. This requires a low f/number collimating lens to be used if the light is to efficiently collected and collimated. This increases the cost and complexity of the lens system.

CLAIMS

1. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween; and

a second signalling device comprising at least one signalling element for signalling with at least one of the signalling elements of said first signalling device; and

wherein said first signalling device further comprises at least one additional optical element for reducing the apparent size of the gaps between adjacent elements.

2. A system according to claim 1, wherein said at least one additional optical element comprises a corresponding plurality of microlenses positioned in front of the signalling elements.

3. A system according to claim 1, wherein said at least one additional optical element comprises at least one beamsplitter, wherein said plurality of signalling elements are arranged in at lest two groups and wherein the at least one beamsplitter and the at least two groups are arranged so that the signalling elements of the at least two groups are effectively interleaved with one another.

4. A system according to claim 1, wherein the at least one additional optical element comprises a second plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween, the second plurality of signalling elements being offset at an angle relative to the first plurality of signalling elements.

5. An apparatus according to any preceding claim, wherein the or each plurality of signalling elements are arranged in an array.

6. An apparatus according to claim 5, wherein the signalling elements are arranged in a regular array.

7. A system according to claim 5, wherein the or each array is a two dimensional array.

8. A system according to claim 5, wherein the or each array is a one dimensional array.

9. A system according to any preceding claim, wherein a lens system is provided in front of the plurality of signalling elements in said first signalling device and a lens system is provided in front of the signalling cell within said second signalling device.

10. A system according to claim 9, wherein the lens system of said first signalling device comprises a

telecentric lens.

11. A system according to claim 10, wherein said plurality of signalling elements are located substantially at the back focal plane of said telecentric lens.

12. A system according to claim 10 and 11, wherein said telecentric lens is a wide angled telecentric lens.

13. A system according to any preceding claim, wherein said plurality of signalling elements comprises an array of light emitters.

14. A system according to any of claims 1 to 12, wherein said array of signalling elements comprises an array of light reflectors.

15. A system according to claim 14, wherein said first signalling device further comprises means for modulating light reflected by or to be reflected by said array of reflectors.

16. A system according to any preceding claim, wherein said second signalling device comprises a plurality of signalling elements.

17. A system according to claim 16, wherein said plurality of said signalling elements in said second

signalling device are arranged in a regular array.

18. A system according to claim 17, wherein one or more of said signalling elements of said second signalling device comprises a vertical cavity surface emitting laser (VCSEL).

19. A system according to claim 17 or 18, wherein one or more of said signalling elements of said second signalling device comprises a light detector.

20. A system according to 19, wherein the or each light detector comprises a photodiode.

21. A system according to any preceding claim, wherein said first and second signalling devices are moveable relative to each other.

22. A system according to any preceding claim, wherein said at least one further optical element is operable for increasing the average packing density of the plurality of signalling elements.

23. A system according to any preceding claim, comprising a plurality of said first signalling devices arranged to signal with one or more of said second signalling devices.

24. A system according to any preceding claim,

comprising a plurality of said second signalling devices each arranged to signal with a respective one of said signalling elements of said first signalling device.

25. A system according to any preceding claim, wherein the signalling elements of said first signalling device are operable to modulate an optical signal to be transmitted to said second signalling device.

26. A system according to claim 25, wherein said signalling elements of said first signalling device are operable to modulate at least one of the amplitude, phase, frequency or polarisation of the optical signal.

27. A signalling device comprising a plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween and at least one further optical element for reducing the apparent size of the gaps between the adjacent elements.

28. A signalling device comprising the technical first signalling device features of any preceding claim.

29. A signalling kit comprising one or more signalling devices according to claim 27 or 28 and a plurality of second signalling devices, each comprising at least one signalling element for signalling with at least one of the signalling elements of said first signalling device.

30. A signalling method using first and second signalling devices, the first signalling device comprising a plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween, the method being characterised by the step of providing at said first signalling device at least one additional optical element for reducing the apparent size of the gaps between adjacent elements.

31. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising means for generating an optical signal; means for modulating the generated optical signal with modulation data; and means for reflecting the generated optical signal towards said second signalling device;

the second signalling device comprising means for receiving optical signals transmitted from the first signalling device; means for retrieving the modulation data from the received signal; means for modulating the received optical signal with modulation data for the first signalling device; and means for reflecting the received optical signal back to the first signalling device.

32. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of reflectors and a light source for illuminating said

plurality of reflectors in common;

the second signalling device comprising a plurality of reflectors each for receiving light from a respective light source and for reflecting the light back to the respective light source.

33. A system according to claim 32, wherein said reflectors are arranged in an array.

34. A system according to claim 32 or 33, wherein said first signalling device further comprises means for modulating the light from said source with modulation data and wherein said second signalling device further comprises means for retrieving the modulation data.

35. A system according to any of claims 32 to 34, wherein said second signalling device further comprises means for modulating the light from said first signalling device with modulation data and wherein said first signalling device further comprises means for retrieving the modulation data.

36. An optical signalling system comprising first and second signalling devices, wherein each of the first and second signalling devices comprises a retro-reflector and at least one of the first and second signalling devices comprises means for generating and outputting an optical signal onto the retro-reflector of said at least one of said first and second signalling devices.

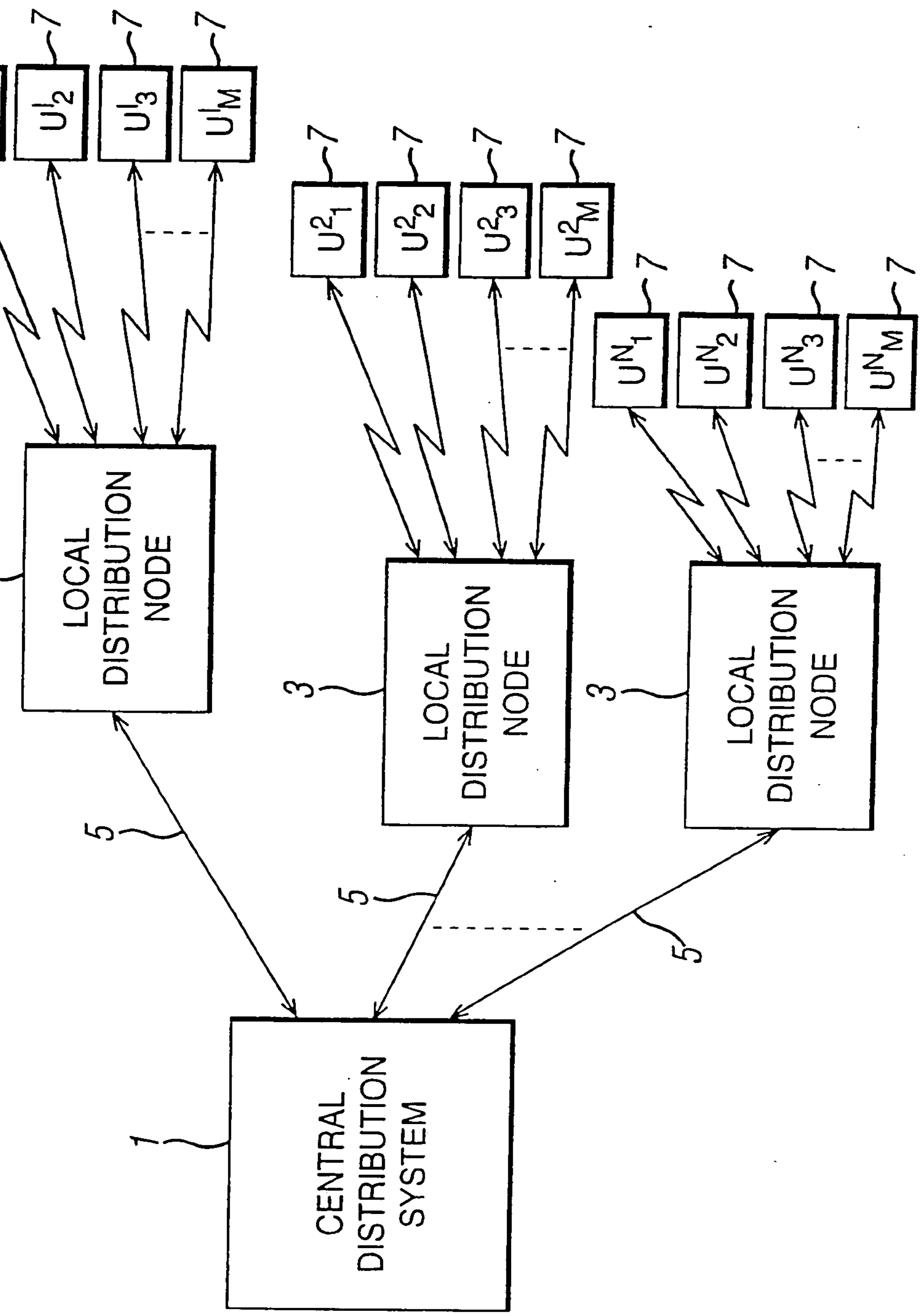
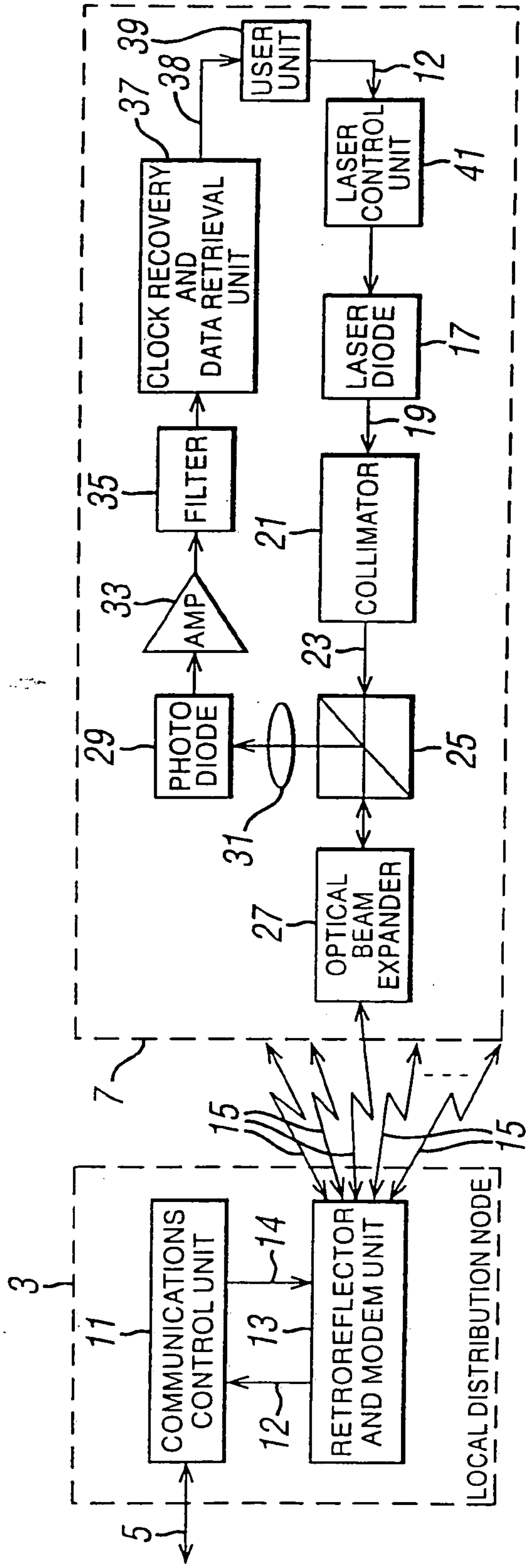

CENTRAL DISTRIBUTION SYSTEM
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
U^1_1 U^1_2 U^1_3 U^1_M
U^2_1 U^2_2 U^2_3 U^2_M
U^N_1 U^N_2 U^N_3 U^N_M
1
3
5
7

FIG. 1


USER UNIT
LASER CONTROL UNIT
CLOCK RECOVERY AND DATA RETRIEVAL UNIT
LASER DIODE
FILTER
COLLIMATOR
AMP
PHOTO DIODE
OPTICAL BEAM EXPANDER
COMMUNICATIONS CONTROL UNIT
RETROREFLECTOR AND MODEM UNIT
LOCAL DISTRIBUTION NODE
39
38
37
12
41
17
19
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14
13
12
5

FIG. 2

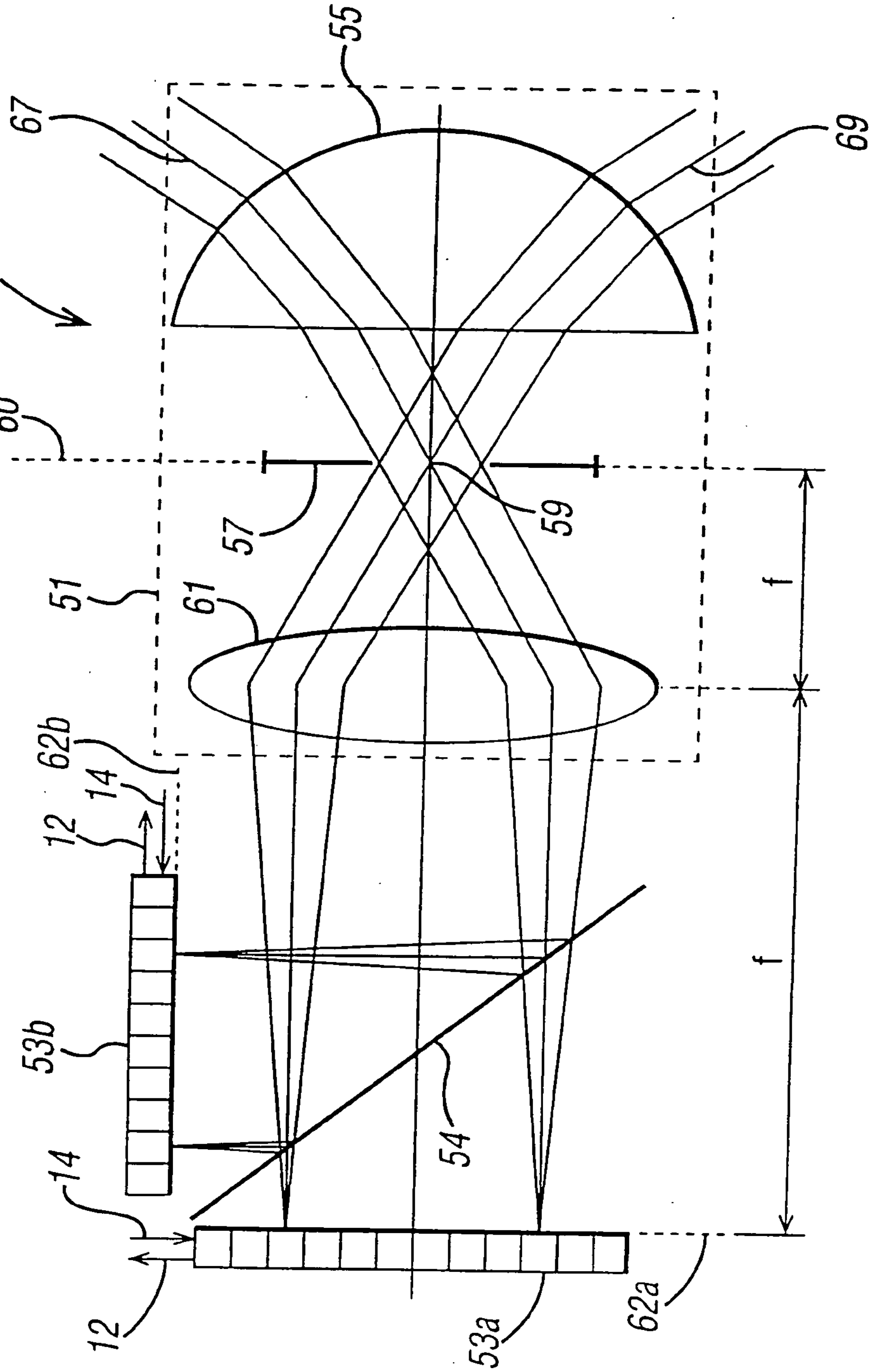
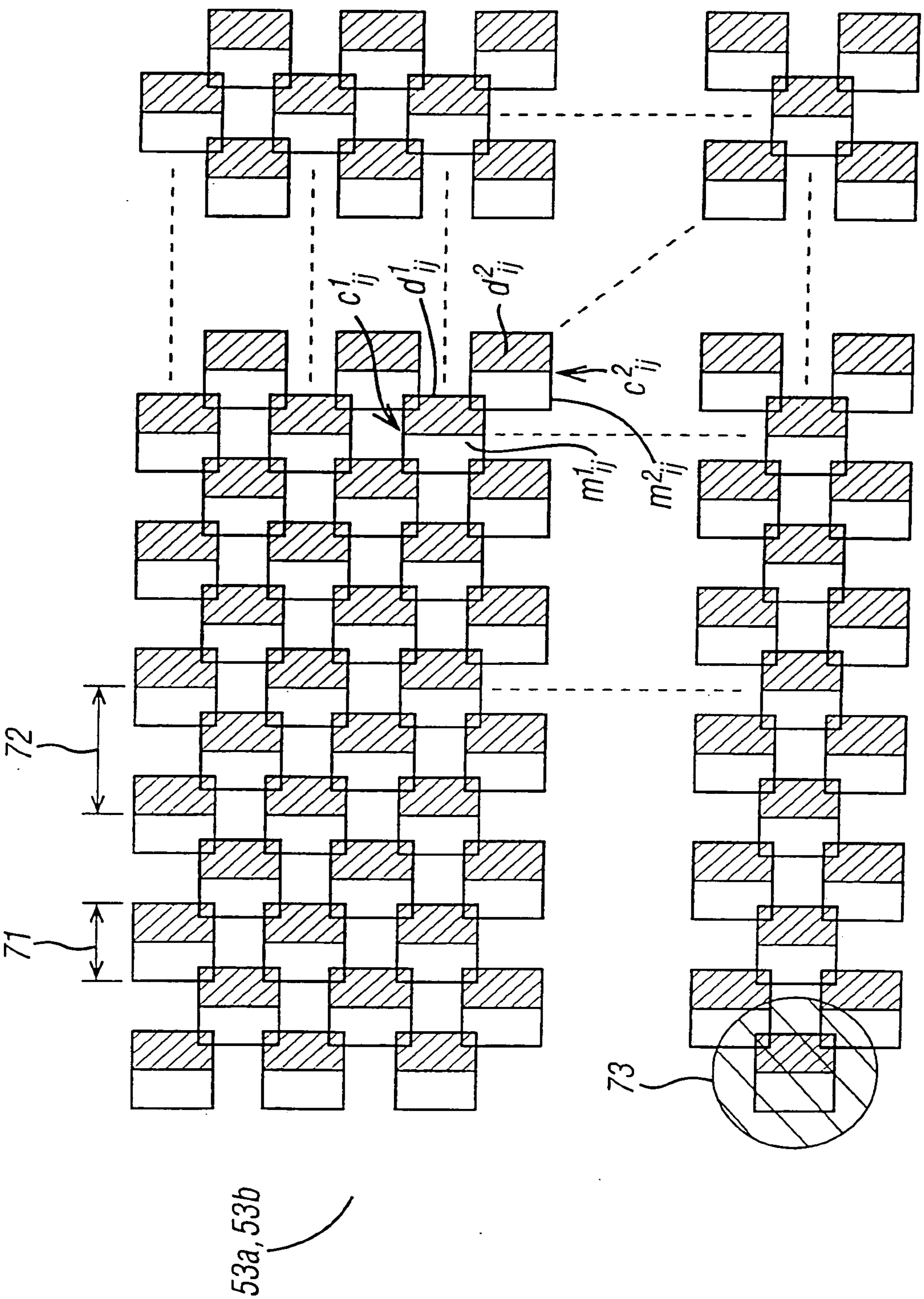
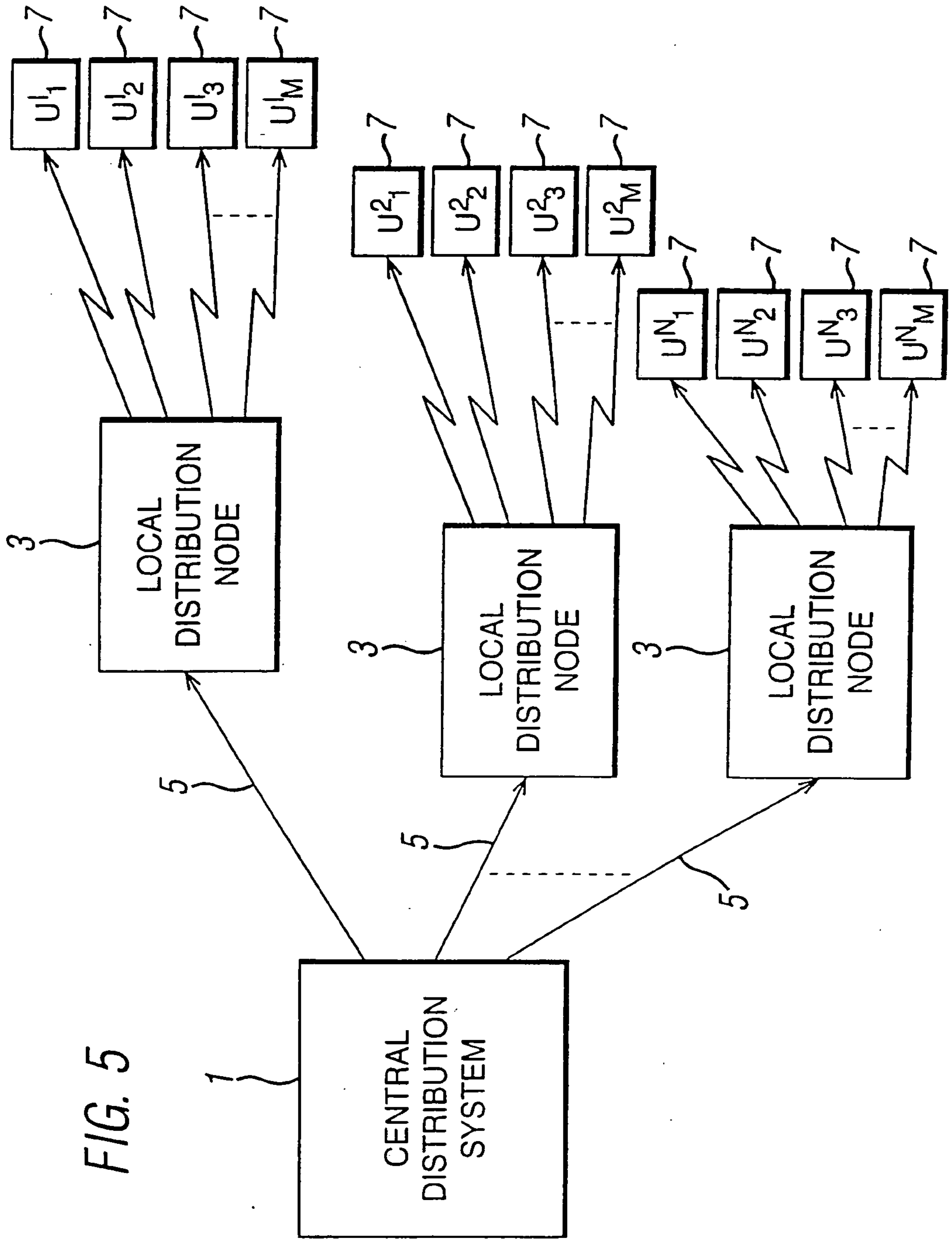


FIG. 3

FIG. 4




CENTRAL DISTRIBUTION SYSTEM
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LOCAL DISTRIBUTION NODE
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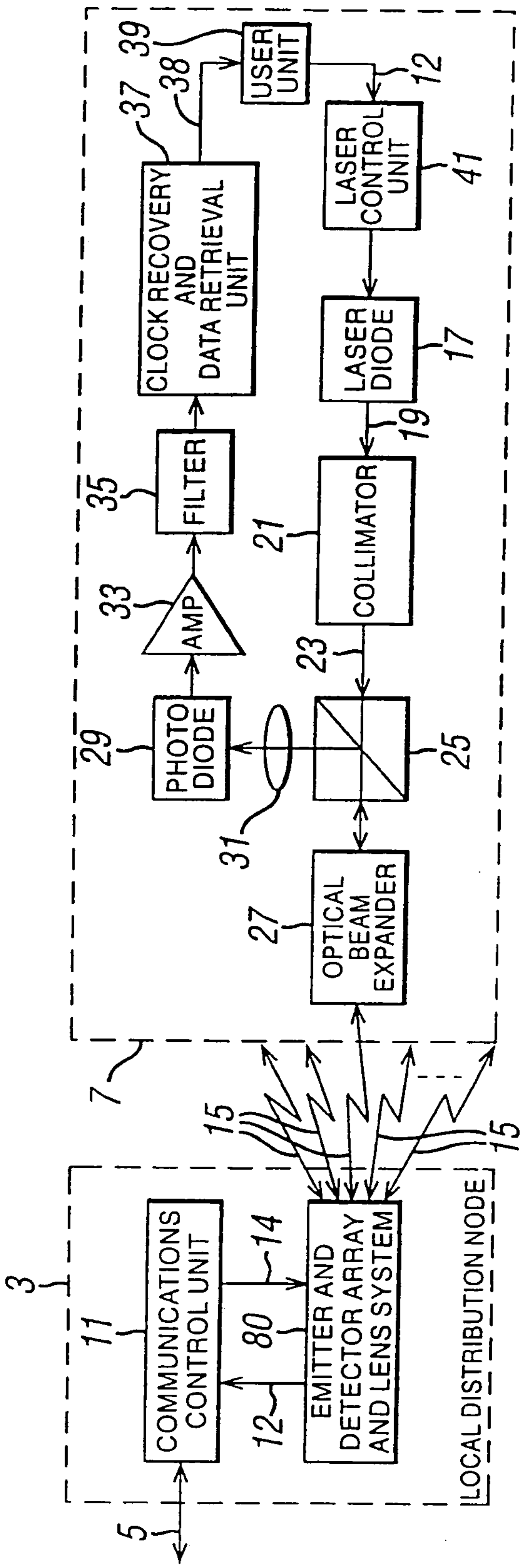
U^1_2
U^1_3
U^1_M
U^2_1
U^2_2
U^2_3
U^2_M
U^N_1
U^N_2
U^N_3
U^N_M
1
3
5
7

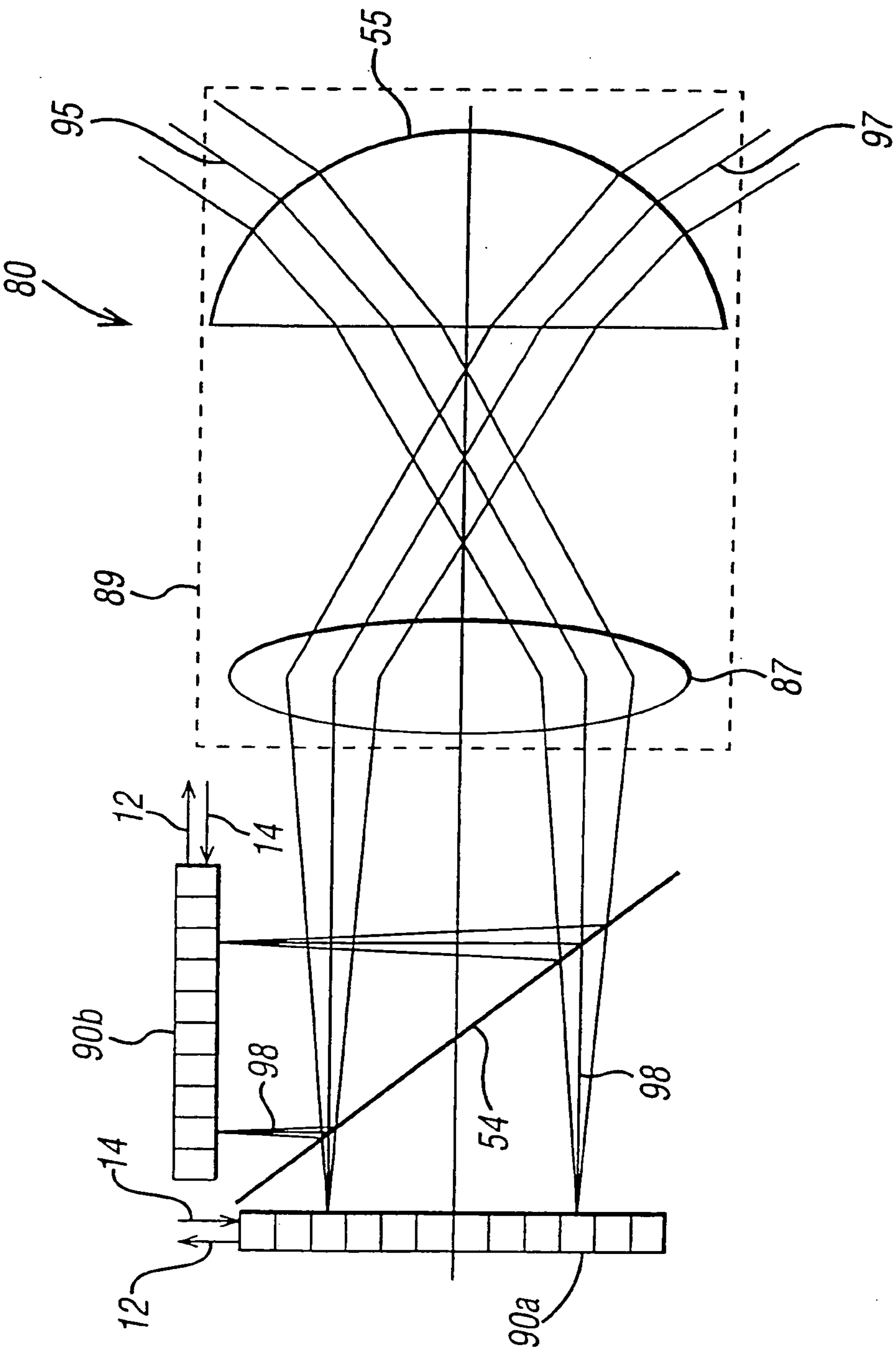
FIG. 5

FIG. 6


USER UNIT
CLOCK RECOVERY AND DATA RETRIEVAL UNIT
LASER CONTROL UNIT
LASER DIODE
FILTER
COLLIMATOR
AMP
PHOTO DIODE
OPTICAL BEAM EXPANDER
COMMUNICATIONS CONTROL UNIT
EMITTER AND DETECTOR ARRAY AND LENS SYSTEM
LOCAL DISTRIBUTION NODE
39
38
37
12
41
17
19
35
21
33
23
29
25
31
27
7
15
15
3
11
14
80
12
5

10/030240

FIG. 7



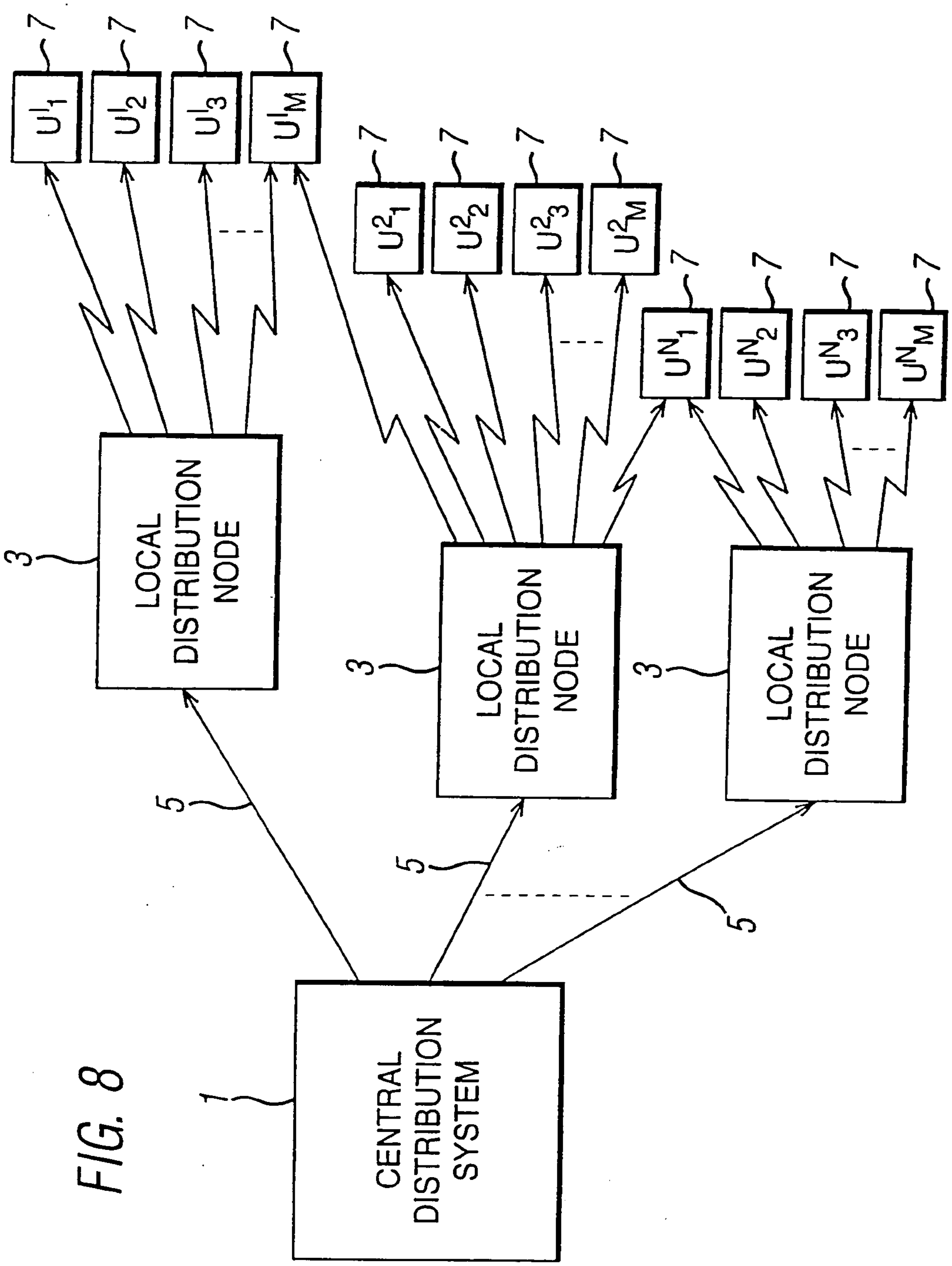

CENTRAL DISTRIBUTION SYSTEM
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
U^1_1
U^1_2
U^1_3
U^1_M
U^2_1
U^2_2
U^2_3
U^2_M
U^N_1
U^N_2
U^N_3
U^N_M
1
3
5
7

FIG. 8

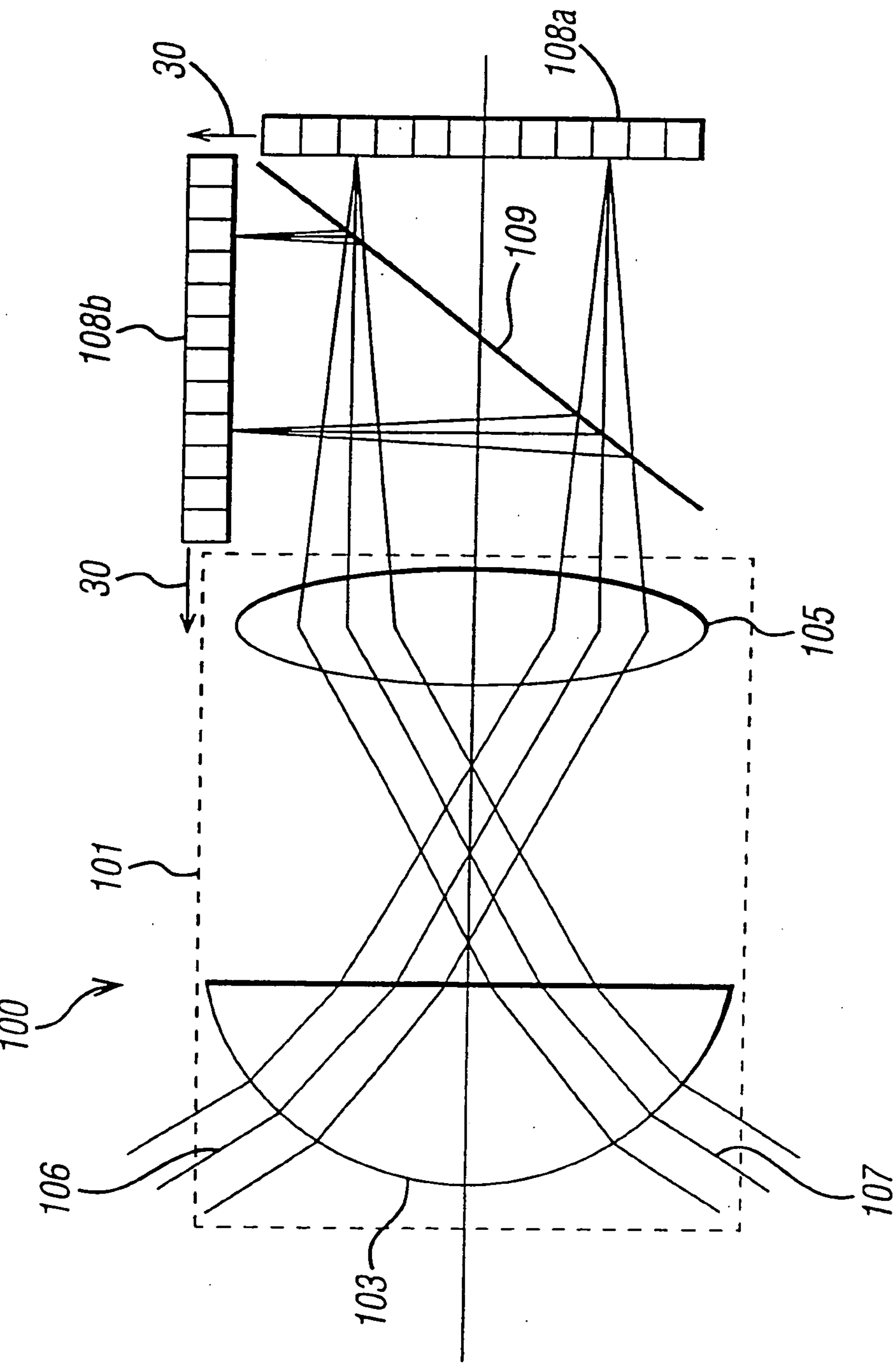


FIG. 9

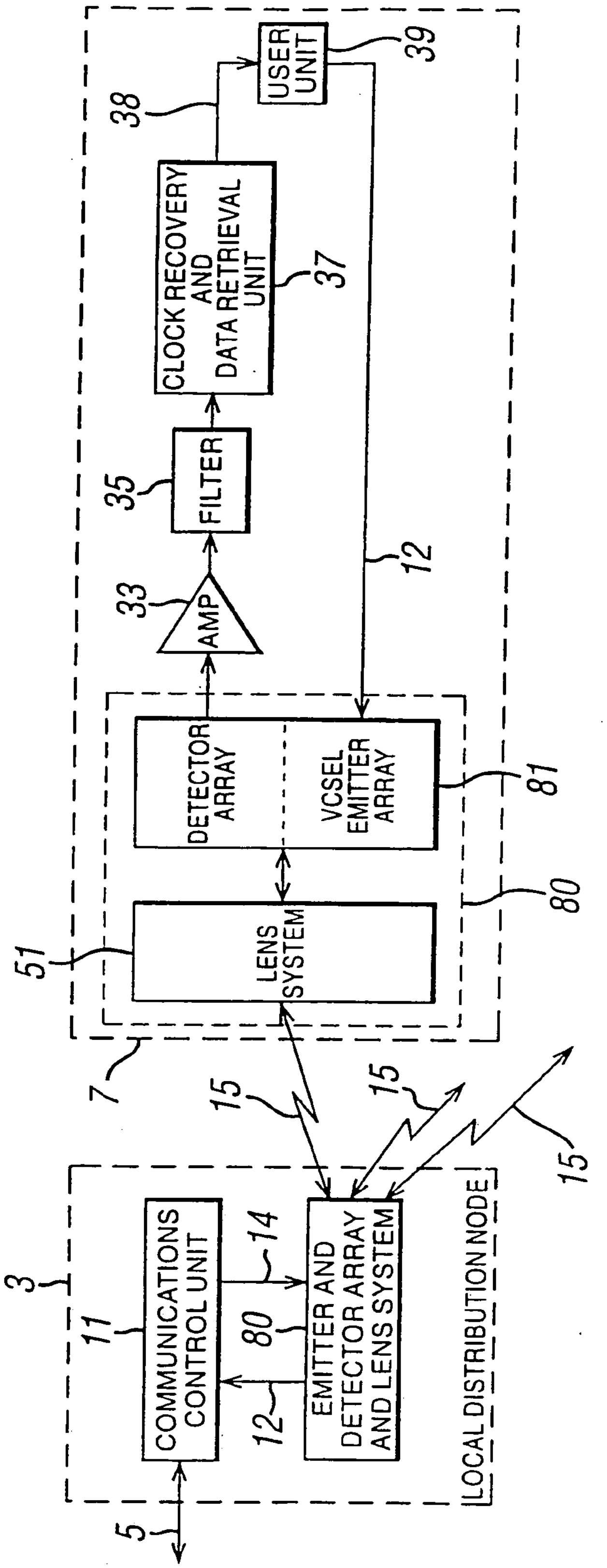

USER UNIT
39
38
CLOCK RECOVERY AND DATA RETRIEVAL UNIT
37
FILTER
35
AMP
33
12
DETECTOR ARRAY
VCSEL EMITTER ARRAY
81
LENS SYSTEM
80
51
7
15
15
15
3
COMMUNICATIONS CONTROL UNIT
11
14
80
12
EMITTER AND DETECTOR ARRAY AND LENS SYSTEM
LOCAL DISTRIBUTION NODE
5

FIG. 10

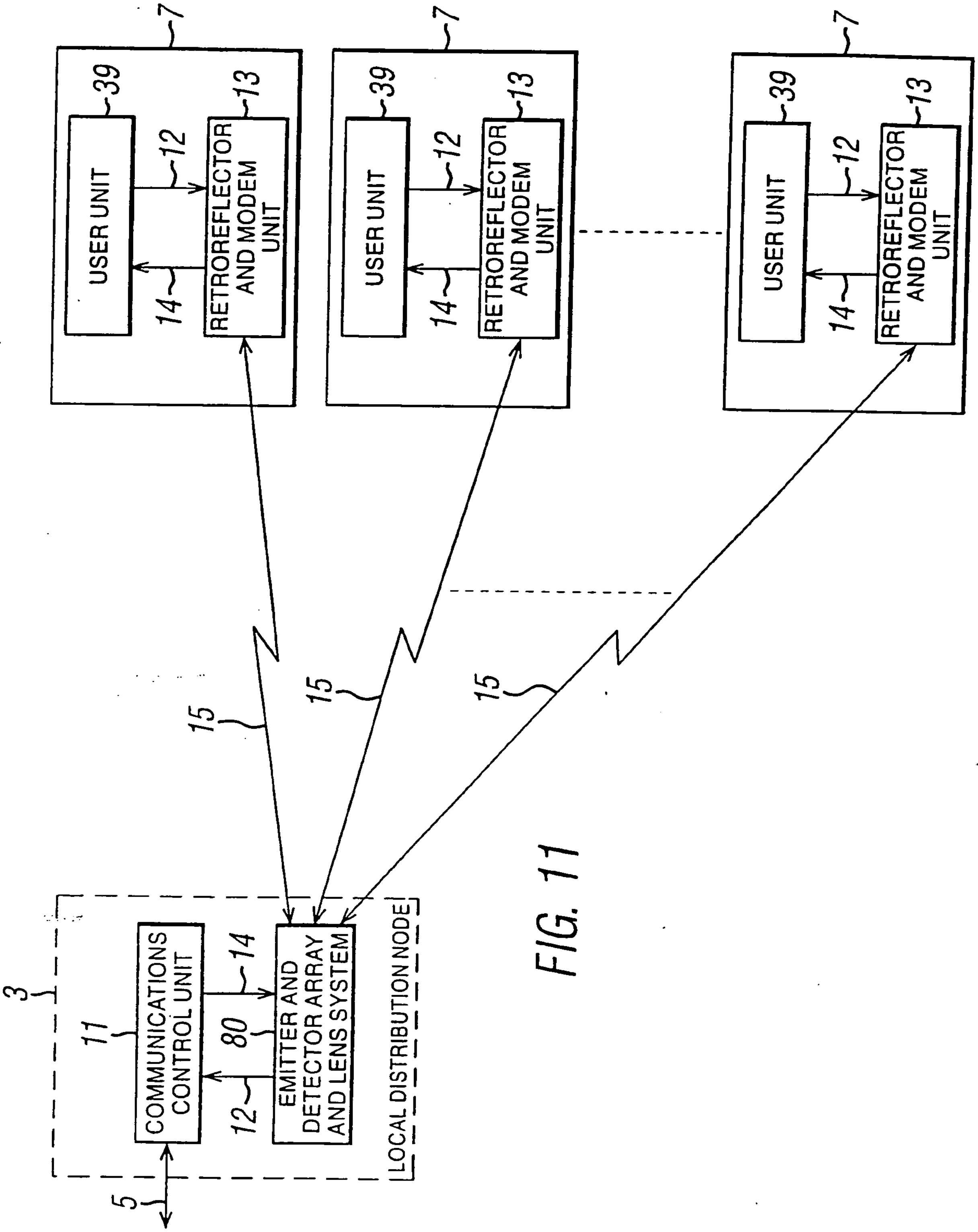

7
39
13
USER UNIT
12
14
RETROREFLECTOR AND MODEM UNIT
15
3
11
COMMUNICATIONS CONTROL UNIT
80
EMITTER AND DETECTOR ARRAY AND LENS SYSTEM
LOCAL DISTRIBUTION NODE
5

FIG. 11

FIG. 12

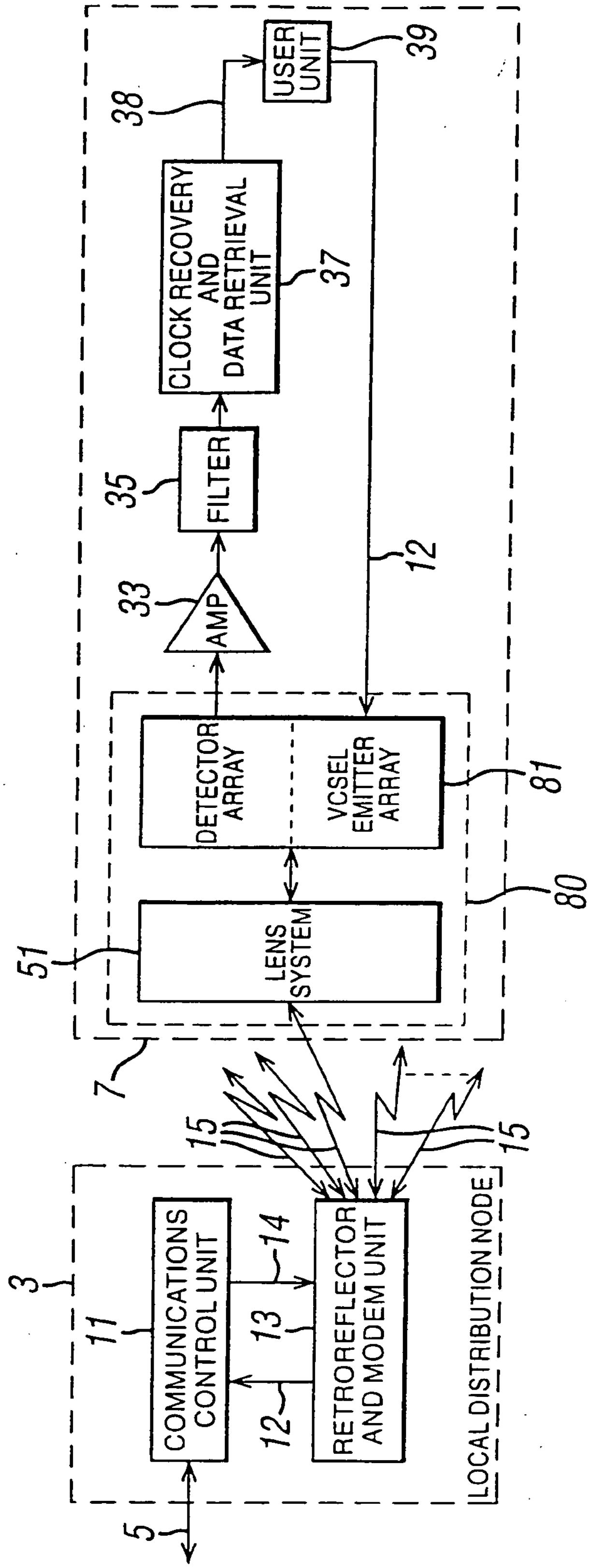

USER UNIT
39
38
CLOCK RECOVERY AND DATA RETRIEVAL UNIT
37
FILTER
35
AMP
33
12
DETECTOR ARRAY
VCSEL EMITTER ARRAY
81
LENS SYSTEM
51
80
7
15
15
COMMUNICATIONS CONTROL UNIT
11
3
14
13
12
RETROREFLECTOR AND MODEM UNIT
LOCAL DISTRIBUTION NODE
5

FIG. 13

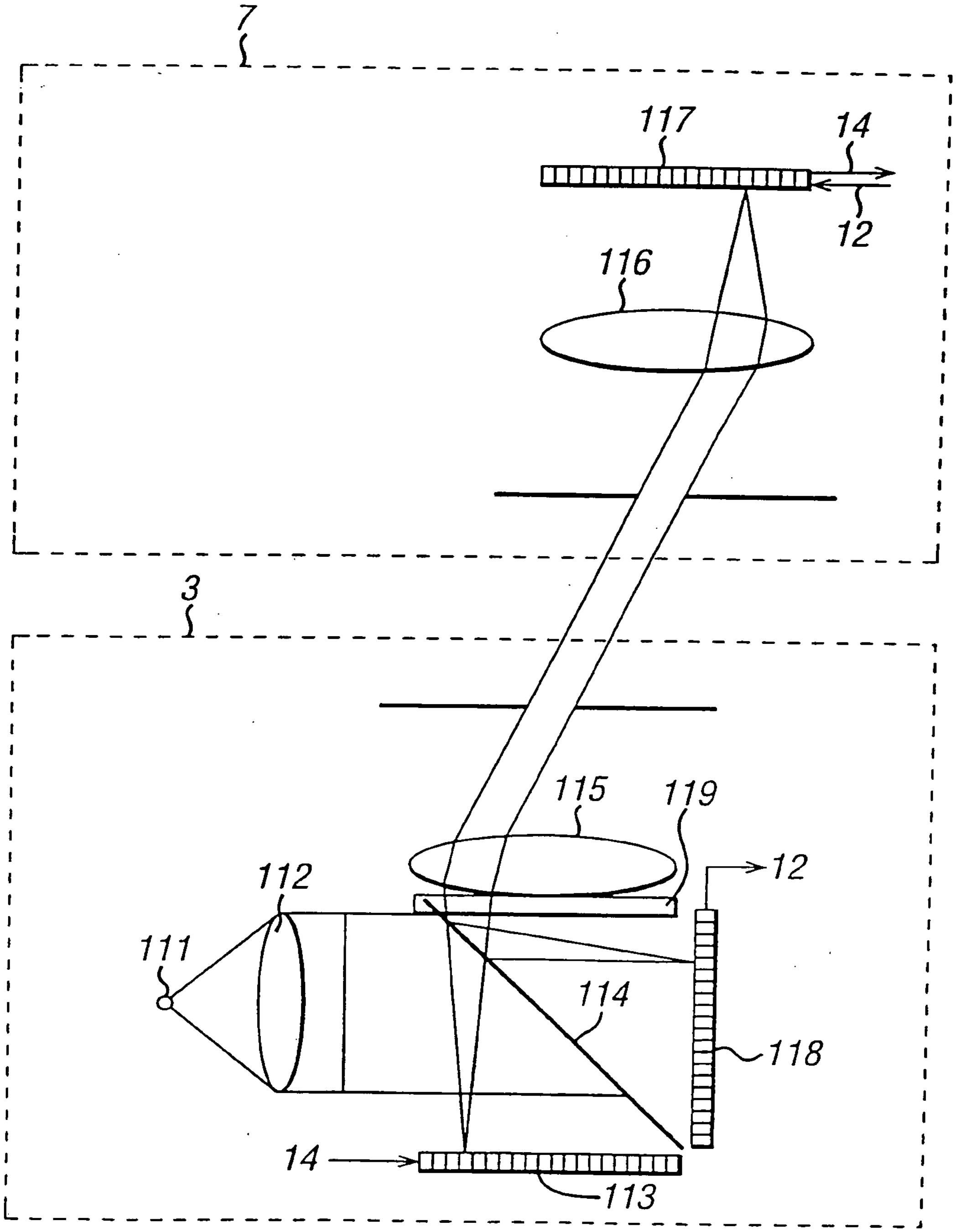


FIG. 14

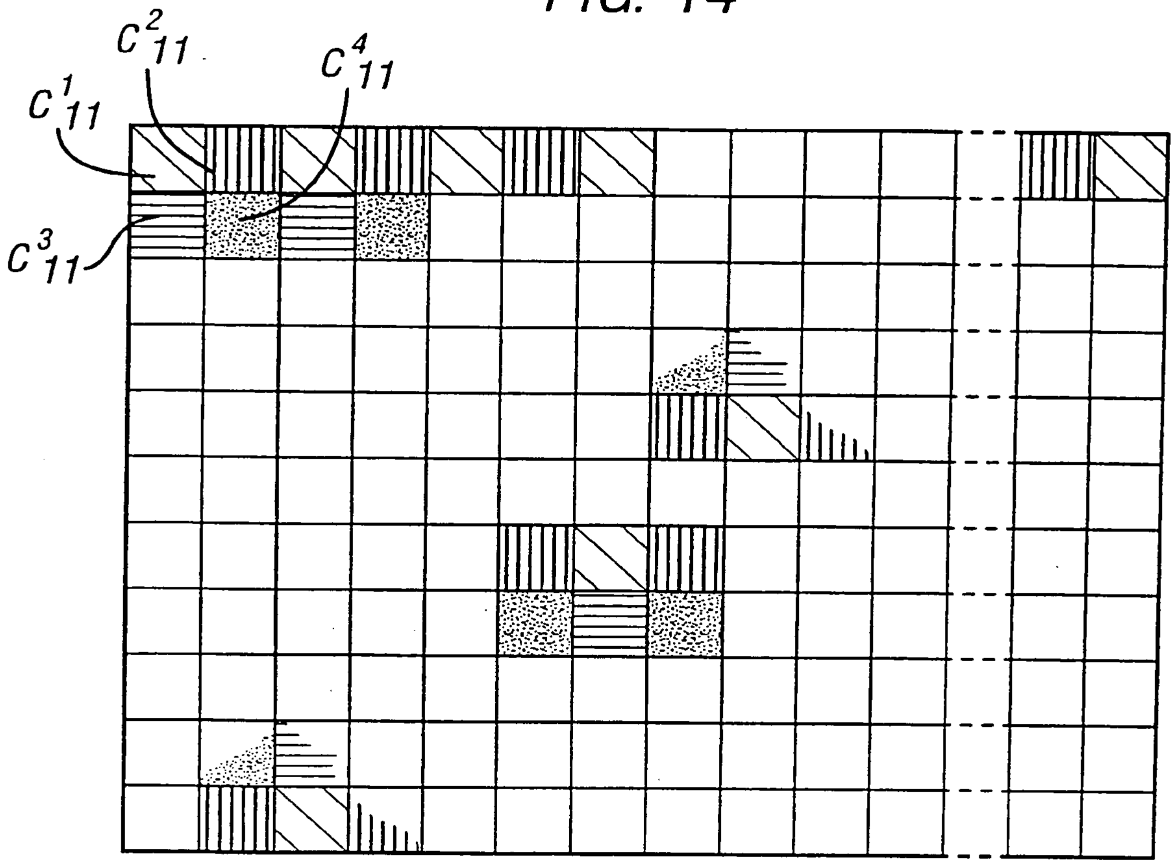


FIG. 15

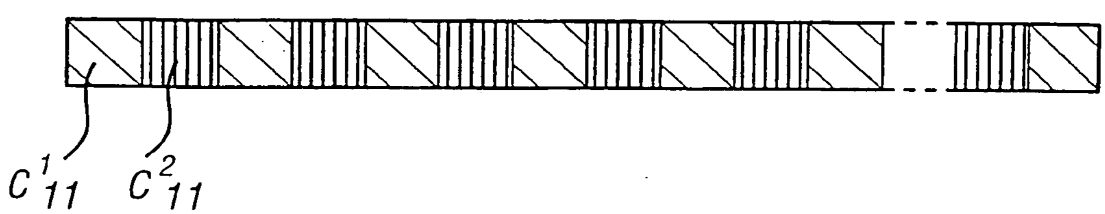


FIG. 16

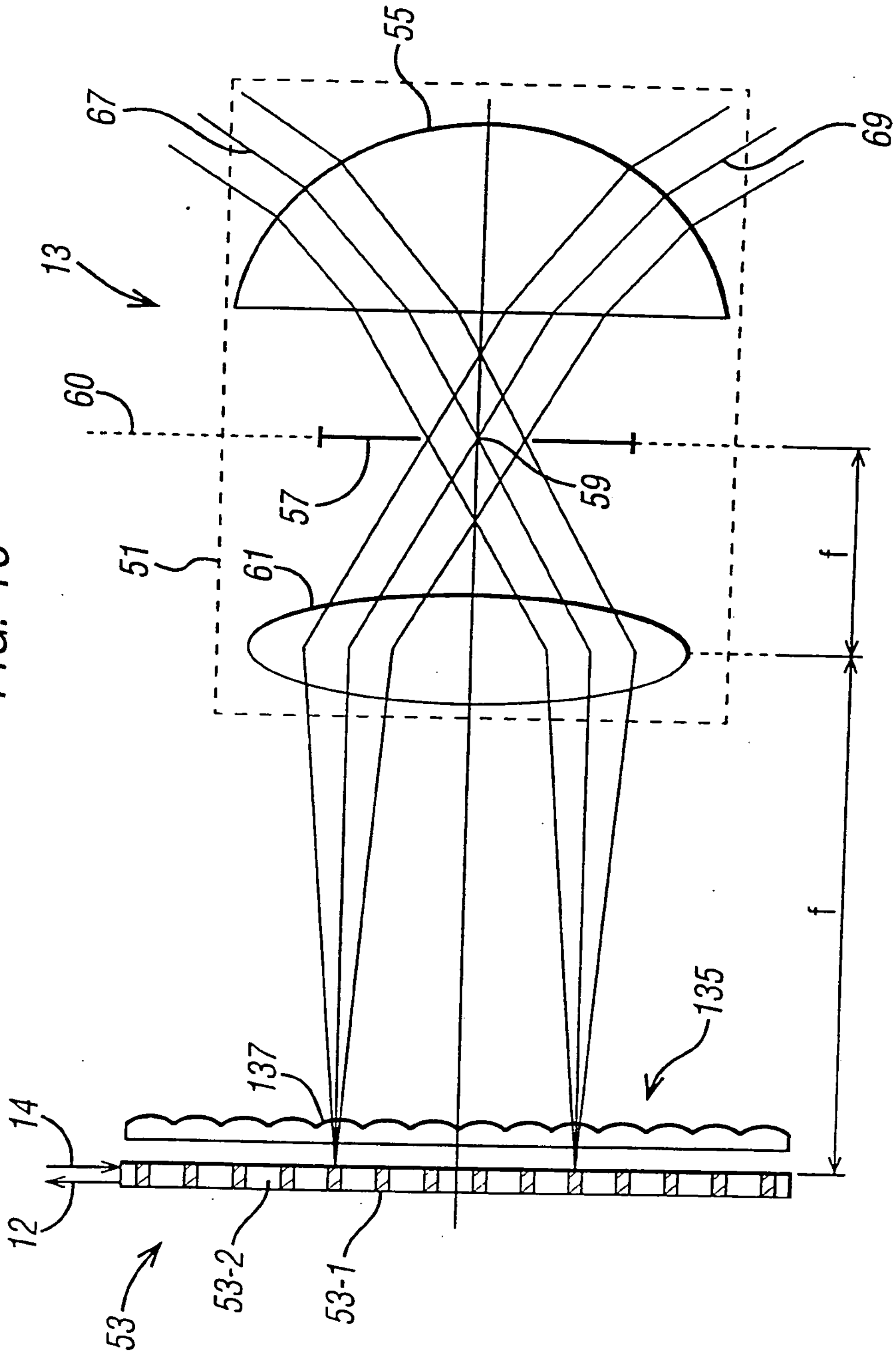
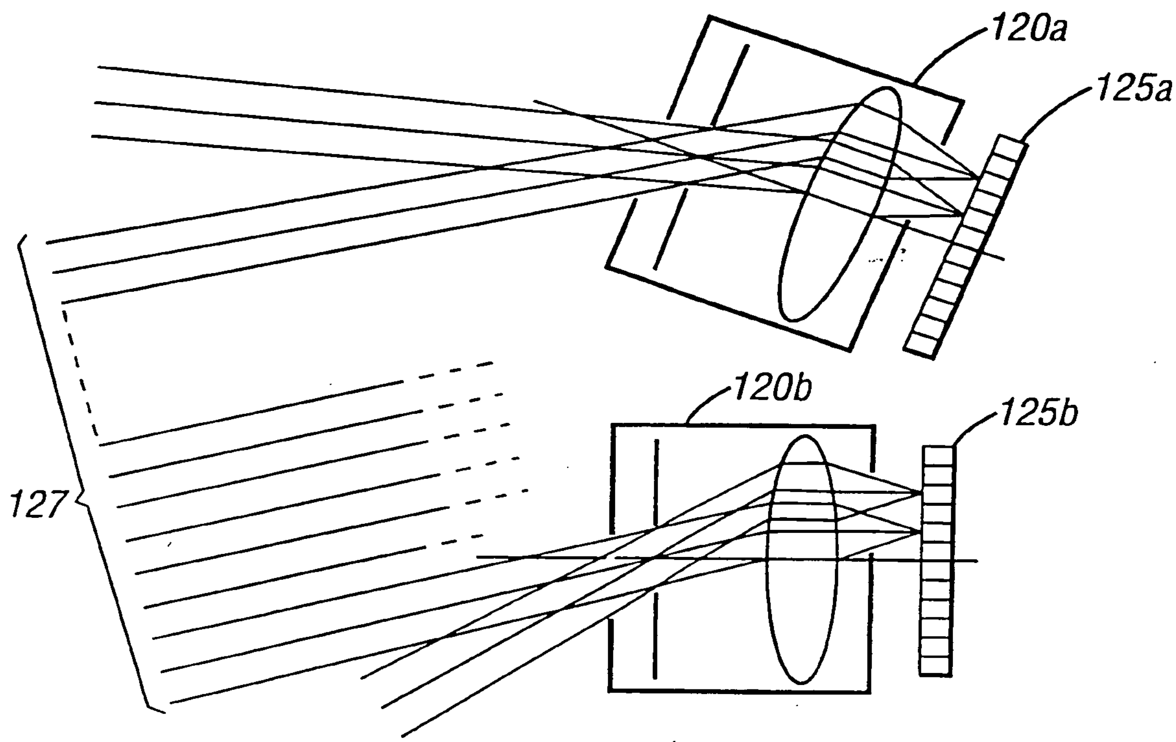


FIG. 17



14

PATENT COOPERATION TREATY

PCT

REC'D 09 OCT 2001
WIPO PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
1829899		
International application No. PCT/GB00/02668	International filing date *(day/month/year)* 10/07/2000	Priority date *(day/month/year)* 08/07/1999

International Patent Classification (IPC) or national classification and IPC
H04B10/207

Applicant
QUANTUMBEAM LIMITED

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 8 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
30/01/2001	08.10.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Phillips, S Telephone No. +49 89 2399 8674

Form PCT/IPEA/409 (cover sheet) (January 1994)

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

   Description, pages:

   1-27 as originally filed

   Claims, No.:

   1-36 as received on 03/09/2001 with letter of 31/08/2001

   Drawings, sheets:

   1/16-16/16 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   ☐ the language of publication of the international application (under Rule 48.3(b)).
   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

   ☐ the entire international application.

   ☒ claims Nos. 31-36.

because:

☒ the said international application, or the said claims Nos. 31-36 relate to the following subject matter which does not require an international preliminary examination (*specify*):
see separate sheet

☐ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. are so unclear that no meaningful opinion could be formed (*specify*):

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☐ no international search report has been established for the said claims Nos. .

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

   ☐ the written form has not been furnished or does not comply with the standard.

   ☐ the computer readable form has not been furnished or does not comply with the standard.

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

☐ paid additional fees.

☐ paid additional fees under protest.

☒ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

☐ complied with.

☐ not complied with for the following reasons:

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

☐ all parts.

☒ the parts relating to claims Nos. 1-30.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-30
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-30
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-30
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Reference is made to the following document:

D1: WO-A2-98/35328

Section I

1. **Claims 1, 27 and 30** are based on original claims 1, 27 and 30 and Figure 3.

2. **Claim 3** is based on original claim 3 and Figure 4.

Section III

In reply to the Invitation to Restrict or Pay Additional Fees, the applicant chose neither to restrict the examination nor to pay additional fees. The examination has therefore been confined to **claims 1-30**. Claims 31-36 have not been examined and should no longer be present in the application.

Section V

1. The application relates to apparatus (**claims 1 and 27**) and method (**claim 30**) for use in an optical signalling system.

2. Document D1 is regarded as being the closest prior art to the subject matter of **claims 1, 27 and 30** and discloses the following features:

   first and second optical signalling devices comprising signalling elements (figure 2); the second signalling device comprising a plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween (figure 4 and page 14 lines 3-9)

   from which the subject-matter of claims 1, 27 and 30 differs in that it also includes at least one additional optical element arranged to reduce the apparent size of the gaps between the elements.

   The subject-matter of **claims 1, 27 and 30** is therefore novel (Article 33(2) PCT).

3. Problem: How to improve performance in an optical signalling system in which light beams from one signalling device may be incident on gaps between elements of another signalling device.

4. Solution: The feature which is new with respect to the available prior art is to include at least one additional optical element arranged to reduce the apparent size of the gaps between the elements. None of the available prior art documents provide any hint to do this and hence the particular solution is non-obvious and considered to be inventive (Article 33(3) PCT).

5. The dependent claims add further features to the independent claims and thus also relate to novel and inventive subject matter and hence meet the requirements of Article 33(2) and (3) PCT.

Section VII

1. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

2. Independent **claims 1 and 27** are not in the two part form in accordance with Rule 6.3(b) PCT.

Section VIII

1. The word "for" is taken to mean "suitable for" (see the Guidelines, PCT/GL/3 III, 4.8) and thus the features which follow "for" do not limit the scope of protection of the claim. This objection is of particular relevance to the subject matter of **claims 27 and 30**, where, for the purposes of this examination, the wording "for reducing" has been taken to mean "adapted to reduce".

2. In addition, the subject matter of the following claim is unclear in the sense of Article 6 PCT for the reason given below:

Claim 28: The feature "first signalling device" has no antecedent basis when claim 28 is dependent on claim 27.

3. In the description of the present application (page 11 line 13), a document is "incorporated by reference". Since the application should be self contained (see Guidelines PCT/GL/3 II, 4.17), this phrase should not be present.

4. There appears to be an error in the statement of dependency of **claim 29**, which appears as if it should have been dependent on claim 28 only (Rule 6.4(a)) PCT).

REPLACED BY ART 34 AMDT

CLAIMS

1. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween; and

a second signalling device comprising at least one signalling element for signalling with at least one of the signalling elements of said first signalling device; and

wherein said first signalling device further comprises at least one additional optical element for reducing the apparent size of the gaps between adjacent elements.

2. A system according to claim 1, wherein said at least one additional optical element comprises a corresponding plurality of microlenses positioned in front of the signalling elements.

3. A system according to claim 1, wherein said at least one additional optical element comprises at least one beamsplitter, wherein said plurality of signalling elements are arranged in at lest two groups and wherein the at least one beamsplitter and the at least two groups are arranged so that the signalling elements of the at least two groups are effectively interleaved with one another.

4. A system according to claim 1, wherein the at least one additional optical element comprises a second plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween, the second plurality of signalling elements being offset at an angle relative to the first plurality of signalling elements.

5. An apparatus according to any preceding claim, wherein the or each plurality of signalling elements are arranged in an array.

6. An apparatus according to claim 5, wherein the signalling elements are arranged in a regular array.

7. A system according to claim 5, wherein the or each array is a two dimensional array.

8. A system according to claim 5, wherein the or each array is a one dimensional array.

9. A system according to any preceding claim, wherein a lens system is provided in front of the plurality of signalling elements in said first signalling device and a lens system is provided in front of the signalling cell within said second signalling device.

10. A system according to claim 9, wherein the lens system of said first signalling device comprises a

telecentric lens.

11. A system according to claim 10, wherein said plurality of signalling elements are located substantially at the back focal plane of said telecentric lens.

12. A system according to claim 10 and 11, wherein said telecentric lens is a wide angled telecentric lens.

13. A system according to any preceding claim, wherein said plurality of signalling elements comprises an array of light emitters.

14. A system according to any of claims 1 to 12, wherein said array of signalling elements comprises an array of light reflectors.

15. A system according to claim 14, wherein said first signalling device further comprises means for modulating light reflected by or to be reflected by said array of reflectors.

16. A system according to any preceding claim, wherein said second signalling device comprises a plurality of signalling elements.

17. A system according to claim 16, wherein said plurality of said signalling elements in said second

signalling device are arranged in a regular array.

18. A system according to claim 17, wherein one or more of said signalling elements of said second signalling device comprises a vertical cavity surface emitting laser (VCSEL).

19. A system according to claim 17 or 18, wherein one or more of said signalling elements of said second signalling device comprises a light detector.

20. A system according to 19, wherein the or each light detector comprises a photodiode.

21. A system according to any preceding claim, wherein said first and second signalling devices are moveable relative to each other.

22. A system according to any preceding claim, wherein said at least one further optical element is operable for increasing the average packing density of the plurality of signalling elements.

23. A system according to any preceding claim, comprising a plurality of said first signalling devices arranged to signal with one or more of said second signalling devices.

24. A system according to any preceding claim,

comprising a plurality of said second signalling devices each arranged to signal with a respective one of said signalling elements of said first signalling device.

25. A system according to any preceding claim, wherein the signalling elements of said first signalling device are operable to modulate an optical signal to be transmitted to said second signalling device.

26. A system according to claim 25, wherein said signalling elements of said first signalling device are operable to modulate at least one of the amplitude, phase, frequency or polarisation of the optical signal.

27. A signalling device comprising a plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween and at least one further optical element for reducing the apparent size of the gaps between the adjacent elements.

28. A signalling device comprising the technical first signalling device features of any preceding claim.

29. A signalling kit comprising one or more signalling devices according to claim 27 or 28 and a plurality of second signalling devices, each comprising at least one signalling element for signalling with at least one of the signalling elements of said first signalling device.

30. A signalling method using first and second signalling devices, the first signalling device comprising a plurality of signalling elements arranged in a predetermined configuration and having gaps therebetween, the method being characterised by the step of providing at said first signalling device at least one additional optical element for reducing the apparent size of the gaps between adjacent elements.

31. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising means for generating an optical signal; means for modulating the generated optical signal with modulation data; and means for reflecting the generated optical signal towards said second signalling device;

the second signalling device comprising means for receiving optical signals transmitted from the first signalling device; means for retrieving the modulation data from the received signal; means for modulating the received optical signal with modulation data for the first signalling device; and means for reflecting the received optical signal back to the first signalling device.

32. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of reflectors and a light source for illuminating said

plurality of reflectors in common;

the second signalling device comprising a plurality of reflectors each for receiving light from a respective light source and for reflecting the light back to the respective light source.

33. A system according to claim 32, wherein said reflectors are arranged in an array.

34. A system according to claim 32 or 33, wherein said first signalling device further comprises means for modulating the light from said source with modulation data and wherein said second signalling device further comprises means for retrieving the modulation data.

35. A system according to any of claims 32 to 34, wherein said second signalling device further comprises means for modulating the light from said first signalling device with modulation data and wherein said first signalling device further comprises means for retrieving the modulation data.

36. An optical signalling system comprising first and second signalling devices, wherein each of the first and second signalling devices comprises a retro-reflector and at least one of the first and second signalling devices comprises means for generating and outputting an optical signal onto the retro-reflector of said at least one of said first and second signalling devices.

10/030240
JC13 Rec'd PCT/PTO 08 JAN 2002

Annexes (amended sheets) to the Preliminary Examination Report

10/030240
JC13 Rec'd PCT/PTO 08 JAN 2002
GB000266
03-09-2001

CLAIMS

1. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of signalling elements each having a common signalling function, the elements being arranged in a predetermined spatial configuration with gaps therebetween; and

a second signalling device comprising at least one signalling element for signalling with at least one of the signalling elements of said first signalling device; and

wherein said first signalling device further comprises at least one additional optical element arranged to reduce the apparent size of the gaps between adjacent elements.

2. A system according to claim 1, wherein said at least one additional optical element comprises a corresponding plurality of microlenses positioned in front of the signalling elements.

3. A system according to claim 1, wherein said at least one additional optical element comprises at least one beamsplitter, wherein said plurality of signalling elements are arranged in at least two groups and wherein the at least one beamsplitter and the at least two groups are arranged so that the signalling elements of the at

least two groups are effectively spatially interleaved with one another.

4. A system according to claim 1, wherein the at least one additional optical element comprises a second plurality of signalling elements each having the same signalling function as the signalling elements of the first plurality of signalling elements, the second plurality of signalling elements being arranged in a predetermined spatial configuration with gaps therebetween, the second plurality of signalling elements being offset at an angle relative to the first plurality of signalling elements.

5. An apparatus according to any preceding claim, wherein the or each plurality of signalling elements are arranged in an array.

6. An apparatus according to claim 5, wherein the signalling elements are arranged in a regular array.

7. A system according to claim 5, wherein the or each array is a two dimensional array.

8. A system according to claim 5, wherein the or each array is a one dimensional array.

9. A system according to any preceding claim, wherein

a lens system is provided in front of the plurality of signalling elements in said first signalling device and a lens system is provided in front of the signalling element within said second signalling device.

10. A system according to claim 9, wherein the lens system of said first signalling device comprises a telecentric lens.

11. A system according to claim 10, wherein said plurality of signalling elements are located substantially at the back focal plane of said telecentric lens.

12. A system according to claim 10 or 11, wherein said telecentric lens is a wide angled telecentric lens.

13. A system according to any preceding claim, wherein said plurality of signalling elements comprises an array of light emitters.

14. A system according to any of claims 1 to 12, wherein said array of signalling elements comprises an array of light reflectors.

15. A system according to claim 14, wherein said first signalling device further comprises means for modulating light reflected by or to be reflected by said array of

reflectors.

16. A system according to any preceding claim, wherein said second signalling device comprises a plurality of signalling elements.

17. A system according to claim 16, wherein said plurality of said signalling elements in said second signalling device are arranged in a regular array.

18. A system according to claim 17, wherein one or more of said signalling elements of said second signalling device comprises a vertical cavity surface emitting laser.

19. A system according to claim 17 or 18, wherein one or more of said signalling elements of said second signalling device comprises a light detector.

20. A system according to 19, wherein the or each light detector comprises a photodiode.

21. A system according to any preceding claim, wherein said first and second signalling devices are moveable relative to each other.

22. A system according to any preceding claim, wherein said at least one further optical element is operable for

increasing the average packing density of the plurality of signalling elements.

23. A system according to any preceding claim, comprising a plurality of said first signalling devices arranged to signal with one or more of said second signalling devices.

24. A system according to any preceding claim, comprising a plurality of said second signalling devices each arranged to signal with a respective one of said signalling elements of said first signalling device.

25. A system according to any preceding claim, wherein the signalling elements of said first signalling device are operable to modulate an optical signal to be transmitted to said second signalling device.

26. A system according to claim 25, wherein said signalling elements of said first signalling device are operable to modulate at least one of the amplitude, phase, frequency or polarisation of the optical signal.

27. A signalling device comprising a plurality of signalling elements arranged in a predetermined spatial configuration with gaps therebetween and at least one further optical element for reducing the apparent size of the gaps between the adjacent elements.

28. A signalling device comprising the technical first signalling device features of any preceding claim.

29. A signalling kit comprising one or more first signalling devices and a plurality of second signalling devices,

wherein each first signalling device comprises a signalling device according to either claim 28 or 29, and

wherein each second signalling device comprises at least one signalling element for signalling with at least one of the signalling elements of said one or more first signalling device.

30. A signalling method using first and second signalling devices, the first signalling device comprising a plurality of signalling elements arranged in a predetermined spatial configuration with gaps therebetween, the method being characterised by the step of providing at said first signalling device at least one additional optical element for reducing the apparent size of the gaps between adjacent elements.

31. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising means for generating an optical signal; means for modulating the generated optical signal with modulation data; and means for reflecting the generated optical signal towards said

second signalling device;

the second signalling device comprising means for receiving optical signals transmitted from the first signalling device; means for retrieving the modulation data from the received signal; means for modulating the received optical signal with modulation data for the first signalling device; and means for reflecting the received optical signal back to the first signalling device.

32. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of reflectors and a light source for illuminating said plurality of reflectors in common;

the second signalling device comprising a plurality of reflectors each for receiving light from a respective light source and for reflecting the light back to the respective light source.

33. A system according to claim 32, wherein said reflectors are arranged in an array.

34. A system according to claim 32 or 33, wherein said first signalling device further comprises means for modulating the light from said source with modulation data and wherein said second signalling device further comprises means for retrieving the modulation data.

35. A system according to any of claims 32 to 34, wherein said second signalling device further comprises means for modulating the light from said first signalling device with modulation data and wherein said first signalling device further comprises means for retrieving the modulation data.

36. An optical signalling system comprising first and second signalling devices, wherein each of the first and second signalling devices comprises a retro-reflector and at least one of the first and second signalling devices comprises means for generating and outputting an optical signal onto the retro-reflector of said at least one of said first and second signalling devices.